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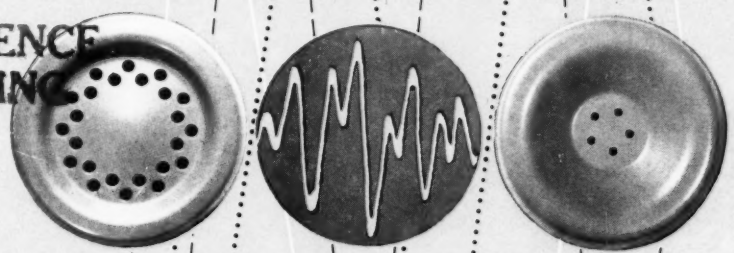

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ELECTRONIC SWITCHING

a new concept for future telephone exchanges — page 62

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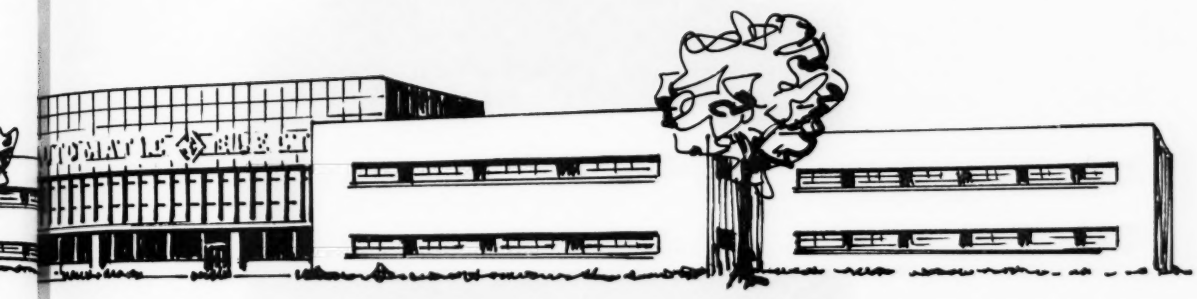

Telephone people have dreamed of a telephone system that would have no moving parts to wear out—and therefore virtually no maintenance problems. The ever increasing interest and notable growth in the field of electronic switching give great promise that—some day—this dream will be fulfilled. Electronic switching will involve many new concepts that will be interesting to telephone people, and we are pleased to present an introduction to this subject, beginning on the next page.

Ways of increasing the efficiency of SATT equipment for telephone exchanges are always the concern of Laboratories. A new device, described in this issue, is the Type 57 Ticket Printer for use with Strowger Automatic Toll Ticketing equipment. For the telephone exchange that does not have complete punched-card equipment, the new Type 57 Printer will read-out data stored in the SATT four- (or five-) channel tape, and type it into a pre-printed ticket form which identifies each item, and is ready for mailing.

ELECTRONIC SWITCHING —

a new concept for future telephone exchanges

By Richard C. Stiles, Senior Project Engineer, General Telephone Laboratories, Inc.

Introduction

In recent years telephone men have been hearing about the possible advent of the art of electronics into telephone exchanges. Many of our readers have come into contact with the field of electronics in transmission equipment, and for those who have, it will be somewhat easier to realize the impact this new technique will have on telephone companies—in operation, economics, and maintenance.

Before discussing this field of electronics I would like to clarify the term *Electronic Switching*. The word "Electronics" itself is used rather loosely these days, and there seems to be some controversy with regard to its meaning. The following definition is attributed to Dr. Imre Molnar of our General Telephone Laboratories:

"Electronics is the branch of science and technology which relates to the propagation of electricity when the electronic theory of matter is required to explain phenomena satisfactorily, and which relates to devices and systems where the application of such principles is predominant."

As far as we are concerned here, the term "Electronics" broadly implies the use of either vacuum-tube devices, gas-tube devices, or solid-state devices such as semiconductors.

Now let's consider the term *Electronic Switching*. Perhaps a very usable definition of this term would be: *"The selective interconnection of channels of communication through connections consisting entirely of electronic circuit elements."* The term "channels of communication" is broad enough to include all forms of electrical communication, and is not limited to the use of telephone channels as we know them today; this is an important fact in considering the future of the telephone business.

It is important to note that within the structure of this definition we cannot include systems in which conventional switch gear is simply controlled by electronic *assists* in the form of electronic register senders, tone generators, or other auxiliary apparatus. The term "Electronic Switching" implies a complete change to an entirely new concept.

Now that we have a clearer understanding of the term "Electronics", let's take a broad look at some of the possible future electronic switching techniques, both short-range and long-range. Let us consider first of all the objectives of our work—the advantages we expect to secure. Then we will describe some of the activity which has been started; and finally take an even longer-range look at some rather surprising concepts for the distant future.

Research and Development

In the face of the ever-increasing efficiency of our present switching equipment, one might wonder why we are so interested in electronic telephone exchanges. Responsible telephone people have doubted that electronics can compete with present techniques in the foreseeable future, from an economic standpoint. Some even wonder if electronic exchanges are technically practical. Perhaps these skeptics should spend some time in telephone research laboratories where they would see the great efforts being directed toward this end — and see large numbers of telephone men who obviously do not share their doubts!

But perhaps we should be more specific about our reasons for being interested in these techniques:

Reduced Investment Cost

We here at General Telephone Laboratories believe that when exchanges of this type are produced on a mass-production basis, the initial cost of services equivalent to those at present being provided will be reduced. At the same time, the new tech-

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niques will make it possible for the telephone company to provide many new services, the cost of which may result in an overall, future increase in investment for switching equipment.

Reduced Floor Space Requirement

As was the case for initial cost, we also believe that exchanges offering services comparable to those of today will require only a small percentage of the floor space presently required. It is also possible that increased services may counteract some of this floor space reduction.

Reduced Maintenance Requirement

It is in this field that we foresee one of the most startling changes. It could be said that one objective of research in electronic telephone switching would be to provide equipment which would give unlimited life, with no maintenance whatsoever. In the years ahead we will approach closer and closer to this objective.

Electronic exchanges will probably be built around transistors — and the life of a transistor is theoretically unlimited. We know, however, that there are practical considerations of manufacture, involving surface effects, which greatly reduce their life, and in fact make the average life expectancy, at present, somewhat unpredictable. Research is concentrating on this problem, and the outlook is that eventually these devices will last the usable life of the rest of the equipment. In this respect, it is probable that transistors will become more reliable than other components which have been taken for granted for years. Such things as capacitors and resistors will require much more research to keep pace with the reliability which is foreseen for solid-state switching devices.

In developing solid-state switching devices specifically for communications, we have a very interesting set of objectives for research. In the missile field, for example, a transistor must be 100% reliable, for a limited period of time, to get the missile to its target. In the telephone business, however, the possibility of a few failures within, say, a six-hour period, is not catastrophic, as long as we know that all but a small percentage of our transistors will last over the economic life of the equipment. To make transistors that will operate for 6 hours without failure requires an entirely different set of research objectives than to make the *average* last for 30 years!

It is easy to visualize that the electronic era will hold many exciting concepts of communication, and that telephone companies of today will become the communications companies of tomorrow. The high speed of electronic circuitry will make possible new switching concepts and also new transmission concepts. New services can be provided easily, thus broadening the scope of operation of communication companies.

Fields of Research

With our interests in electronic switching established, let's review the three principal fields of research which are under consideration at the present time—memory, transmission, and control circuitry.

Memory

This field may surprise some of our readers. Large digital computers in use today have a basic memory of several hundred thousand bits of memory (a bit is a single memory cell). The Strowger switch in your switching system remembers that it is supposed to stay connected to a particular terminal and does so until told to release. The relay also can remember one bit of information, in that it can be made to stay operated until told to release — and control circuitry can be made to examine that "memory cell" to determine what is stored there, in either an operated or an unoperated condition.

Large electronic systems of the future will probably require several million bits of memory, and it will be necessary to have access to any bit in a matter of a few microseconds. Most memory functions will be centralized in a common memory system with a complex *logical network* to distribute this information as required. We will discuss some uses for such memory systems later in this article.

Transmission

Our second principal field is that of transmission techniques. The basic problem is the transmission of a signal from one line to another, and there are several ways in which this can be accomplished electronically. Unlike present intra-office transmission systems, however, electronic systems require a strict limitation of power, so we have a problem in deciding which type or types of transmission technique would be most suitable for our switching systems.

Notice the rather surprising fact that a switching engineer is suddenly talking about transmission; this is quite significant, as it seems a certainty that in the

future the interests of the switching engineer and those of the transmission engineer will become similar. It is probable that the switching systems of the future will extend over such distances that what we consider today as point-to-point transmission will become an integral part of a switching system.

Control Circuitry

The third field of research is control circuitry. It seems certain that systems of the future will be *common control* systems. This leads to circuit techniques which are similar to those of digital computers. We might visualize the control system as the link between the memory and the transmission network. We must provide the logical networks of control which will place required information in the memory at the proper place and time, and then extract it as desired, for use in controlling the transmission network. These parts of an electronic switching system may be combined in many ways, to produce different types of systems. In our Laboratories, we have worked on several of them.

"Crosspoint" Systems

The first type of system which we will discuss is the electronic equivalent of the crossbar system, and is commonly known as the crosspoint type. First, let's define the term *crosspoint*. Basically, a crosspoint is a switch which can be used to connect two conductors together; it gets its name from the fact that such switches are usually arranged (as shown in color in Figure 1) in an array very similar to that of contacts of a cross-bar switch. Here we can see two sets of conductors, carrying input and output signals, joined together, as required, by the crosspoints. The control system acts to select which crosspoint of the group should be used, and "turns it on" as required. We might compare this arrangement with that of a crossbar switch—in which a definite number of conductors in each direction are grouped in a mechanical arrangement, with metallic contacts as the crosspoints. In the electronic crosspoint system the crosspoints may be used as required, and are not limited to any particular arrangement. This gives the circuit designer greater flexibility.

There are many types of crosspoints which could be used, although some are not practical for use in a telephone system, because of their cost.

Vacuum Tube

Perhaps one of the most obvious electronic crosspoints, for example, would be the vacuum tube, arranged as shown in color in Figure 2. In this circuit the control of the cathode could effect transfer of a signal from an input lead to an output lead. Crude as this would be, there is something significant about it. It can be seen that this is a one-way circuit, and information cannot be transmitted in both directions; it would require two crosspoint systems to effect two-way transmission. Thus, only in the electronic equivalent of a 4-wire switching system could the vacuum tube be used as a crosspoint. And this suggests the rather curious fact that, by using certain techniques, it may be easier to produce a 4-wire electronic switching system than a 2-wire electronic system! The vacuum tube is used here only as an illustration, however—it is improbable that it will ever be used as a crosspoint in future electronic telephone switching systems.

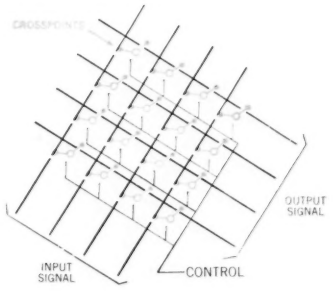

Figure 1. Basic Principles of Crosspoint Switch

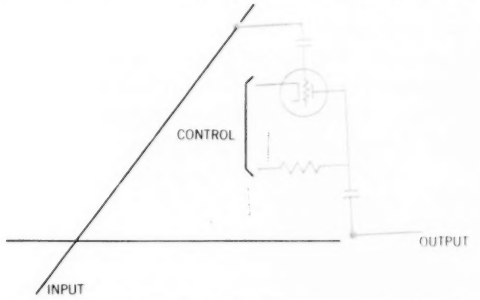

Figure 2. Vacuum Tube Triode as a Crosspoint

Gas-Discharge Tube

One component which might be used as a crosspoint on a practical basis is the gas-discharge tube, as shown in color in Figure 3. This device (a two-terminal device which might be used to transmit information in either direction) provides essentially an open circuit until the gas ionizes, following which it will conduct substantial amounts of current at a low dynamic impedance. Unlike the triode vacuum tube, the gas tube does not require filament power, and this makes it even more enticing. A further advantage of this device is its method of control; it is ionized by a high voltage (100-200 volts), applied to the same two conductors over which the signal will pass after breakdown. This eliminates a separate control wire to the device. On the "disadvantage" side is the physical size of gas tubes, their light-sensitive characteristics, and the relatively high voltage required for breakdown.

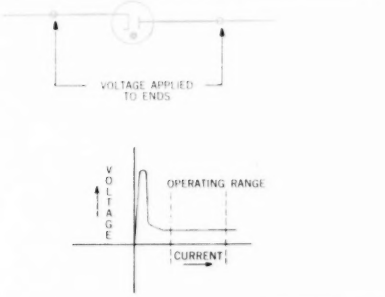

Figure 3. The Gas-Discharge Tube as a Crosspoint

Diode "Gates"

A third type of crosspoint, shown in color in Figure 4, would consist of diode *gates*, controlled by a bi-stable magnetic device, such as a ferrite "core". In this technique, this square loop magnetic material is used to turn the diode crosspoint "Off" or "On". The core can be magnetized in a particular direction by a pulse, and it will remain that way until a pulse of opposite polarity is applied. In its "On" condition it permits current to flow in the diode gate in the transmission circuit. All of the components of this crosspoint could be encapsulated together, to form a convenient mechanical package, but a package of this sort would probably be at least twice the size of a gas-tube type of crosspoint.

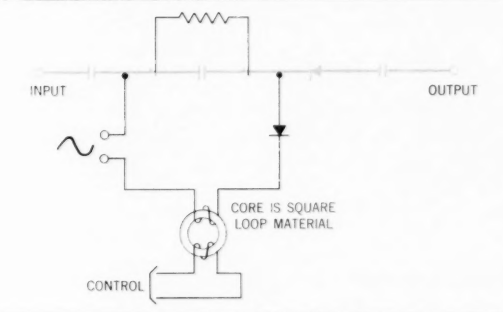

Figure 4. Magnetically Controlled Crosspoint

Transistor

A fourth type of crosspoint would be the transistor. As was the case for the vacuum tube, crosspoints using a single transistor would be unidirectional, and not particularly attractive. However, two transistors — an NPN and a PNP — could be coupled together, as shown in color in Figure 5; here we have a bi-stable circuit combination exhibiting the same negative-resistance characteristic as the gas tube. This combination is a 2-terminal device and could be used on a practical basis.

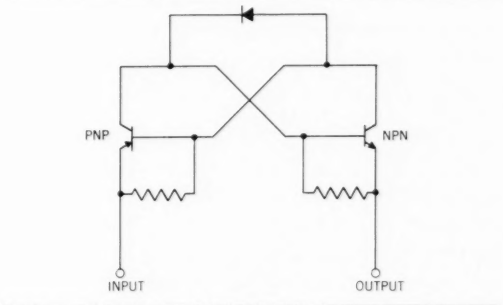

Figure 5. Two Transistor Crosspoint

PNPN "Package"

There is one more crosspoint, however — and it appears to be the most promising. Combining the characteristics of the two transistors of Figure 5 into one transistor, it consists of four layers of semi-

conductor material arranged in a PNPN "package", as shown in color in Figure 6. This device is no larger than the standard transistor, yet can be used, alone, as a crosspoint. It has a desired breakdown characteristic and it can pass an adequate current.

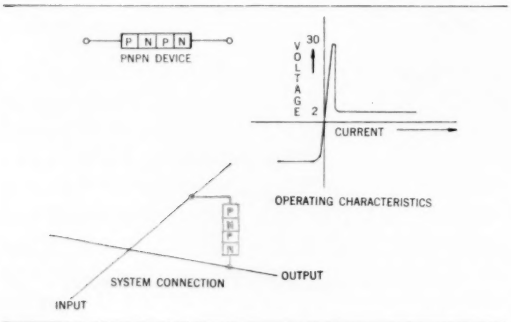

Figure 6. The PNPN Crosspoint

In addition, its breakdown voltage is sufficiently low that it can be driven with conventional transistor circuitry. This appears to be the most promising crosspoint device on the horizon at present. Transistors of this type are being manufactured on a limited basis, and the ultimate outlook is that they can be produced in substantial quantities for less than a dollar each.

A Typical Crosspoint Arrangement

Let us now consider the arrangement of these crosspoints into switching stages. Figure 7 is a simple arrangement for trunking between 10 lines with 3 conversations. By placing a crosspoint circuit element at each crossing of the lines (as shown in color), any line can be coupled to any other. In a large exchange the switching stages of this sort may be coupled together into a 4-stage network as shown in color in Figure 8. Here you can see that certain trunks have access to certain switching stages; also that the number of trunks from each stage matches the number of succeeding switching stages. The process of determining how many of these trunks to use is a matter of traffic analysis and calculation; for a given calling rate and holding time, the desired number of trunks can be calculated by using probability equations based on telephone traffic.

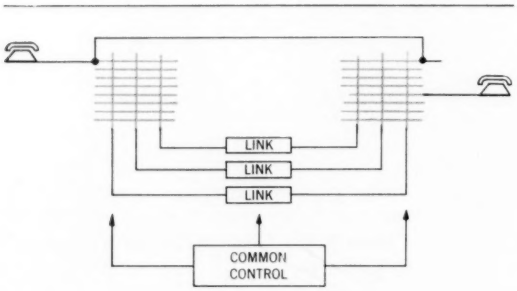

Figure 7. Basic Crosspoint System

In a network of this type we consider the calling lines and called lines separately. This means that each of the lines in any group has an appearance in two switching stages (this is somewhat analogous to the line multiple to the connector banks, in a Strowger system). Note that this results in a symmetrical network, as shown in Figure 8. The control circuit at the center of the network is used to connect the two parts of the network together, and to supply control of the established connection. One might wonder why the right half of this network is required, and why a connection would not be established from a line through the network to the control circuit and then back out to the called line, thus dispensing with the multiple to the other half of the network. If this procedure were to be followed, however, the left half would require twice as many crosspoints for the same traffic; the "double-sided" network thus proves more convenient, without requiring any increase in the number of crosspoints.

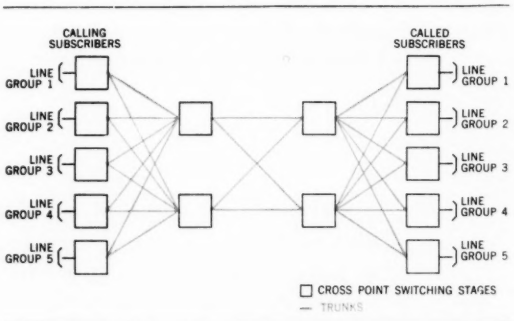

Figure 8. Multi Stage Network

The accompanying chart (Figure 9) shows most of the information required in storage in order to

establish a call through a crosspoint switching network. One of the greatest problems in a network of this type is in locating a given line number. The calling and called parties' numbers must be translated into the *machine language* to be effectively used to locate a group of bits in the memory. These bits are read out at will, and the coded output is then reduced by logical circuitry to a pair of leads in the network. The number of bits required for network translation and location would vary in accordance with the size of the network, but if we were to use a binary decimal type of coding, we could expect to use a total of 20 bits for a 4-digit number. It may be interesting to note that the storage of dialed information is not particularly difficult, and requires very few bits of information.

System Memory Requirements

MEMORY FOR 2000-LINE OFFICE

Function	*Bits*
Network Translation and Location	40,000
Storage of Dialed Information	3,000
Line Identification and Condition	8,000
Trunks and Miscellaneous	9,000
Sub Total	60,000
Logical Control	60,000
Total	120,000

—or an average of 60 bits per line, not including rate and route information for D.D.D.

Figure 9

Line identification and condition information is more complex. One form of control of the line circuits uses a sampling technique. All lines are sampled, on a continuous basis, by an electronic scanner which is continually scanning all lines in a group, in search of any change from the preceding sample. When a line initiates a call, a change is indicated in its memory cells, and this change can be used to further activate additional memory circuits associated with register equipment. The line is sampled several times during each dial impulse; it is probable that 4 bits of memory will be required for each line. (Here is an interesting comparison to electromechanical technique. You would have shuddered at the possibility of using 4 relays per line to do this job; four bits of electronic memory, however, seem rather a small price to pay for line identification and condition information.) After we have added in some miscellaneous bits for trunks and miscellaneous control, we see that we have 60,000 bits of memory required for a 2000-line office — a rate of 30 bits per line. This amount of electronic memory is required for direct control of the switching network.

Logical Control

There is another, equally important field for memory systems in electronic switching — namely, *logical control* — and this will probably require another 60,000 bits of memory, in a 2000-line system. This use of memory cells as "logical" elements of a switching system needs some explanation. Logic is basically a correlation of known facts to form additional conclusions. In circuitry we can compare two or more input leads to indicate a "yes" or "no" conclusion on an additional lead — which could be designated the "output" lead. For example, if pulses appear on both input leads simultaneously we can produce a pulse on the output lead. If pulses do not appear simultaneously on the input leads, no pulse will be present on the output lead. This drawing of conclusions from two separate facts is *logical control.*

The conventional method of accomplishing logical control is with the use of diodes and resistors. However, memory cells can also be used for this purpose, if they can be made cheaply enough. Some conventional logical-control circuitry would, however, be required to control the memory logic, so not all of the logical circuitry can be of the memory type. (It must be emphasized that these memory cells would not be sufficient to provide rate and route information for Direct Distance Dialing and automatic toll ticketing systems. This would be an additional memory requirement to be placed on the memory systems of toll centers.)

It is the function of the control circuitry to tie together the transmission network and the memory system. One important phase of this part of the system is the control of all auxiliary circuitry, such as trunk circuits and signaling tone generators.

Now we have an entire crosspoint system, as shown in Figure 10, which offers great possibilities. The system can easily be transistorized, since there

are not very high frequencies or high currents involved. Because all transmission is done on an audio basis, test procedures are easier. A great disadvantage, however, is the tremendous number of cross-

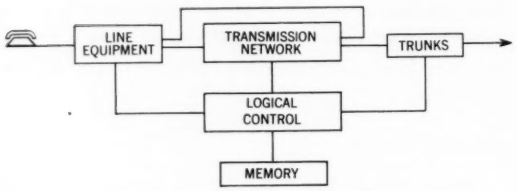

Figure 10. Crosspoint Switching System

points involved; this number may vary from 15 to 25 per line, depending on design — with the figure of 20 per line being a reasonable average. At this rate the 40,000 crosspoints required for a 2000-line system present a formidable economic obstacle. At present the PNPN crosspoint sells for approximately $6.00, but this is a small-quantity price; the ultimate outlook is for the price to drop to $1.00 or less.

The Time-Division-Multiplex System

This entirely different technique for building electronic switching systems also occupies a very important place in our future planning. Development of Time-Division-Multiplex systems has been under way for some time — in fact, Automatic Electric exhibited a small P-A-X of this type at the United States Independent Telephone Association Convention in 1956.

Most telephone men are familiar with the manner in which carrier systems "stack" speech channels onto a single transmission medium by using a different band of frequencies for each channel; this is a frequency-division system. A time-division-multiplex system, on the other hand, samples a signal on a *repetitive* basis, and transmits these samples in a definite relationship of time with respect to samples of other channels. This principle is illustrated by a diagram of the speech signal in Figure 11. Here, a signal which has been sampled periodically, three samples for each half-cycle, is transmitted as a series of pulses (shown in color) and then reconstructed as a series of pulse amplitudes. The transmission medium is required only during the sampling periods; between these periods the same equipment is available to transmit other channels. Thus the transmission medium is *time-shared* for maximum efficiency.

This technique is possible only because it is not necessary to transmit 100% of the time in order to recover intelligence from a transmitted signal. The question is, *How much must we transmit in order to recover the desired degree of intelligence?* Information theory is too complex a subject to discuss here, but we can extract certain fundamentals which will give us a partial understanding.

"Sampling"

Let's start with the signal which we desire to transmit, and assume that this signal will never exceed 4000 cps (a valid assemption for telephone channels of today). In the transmission of two signals of different frequencies, one can be considered the basic carrier signal, the other a modulating signal. The resultant will be not a single frequency, but four separate frequencies — those of the carrier, the modulating signal, the carrier plus the modulating signal, and the carrier minus the modulating

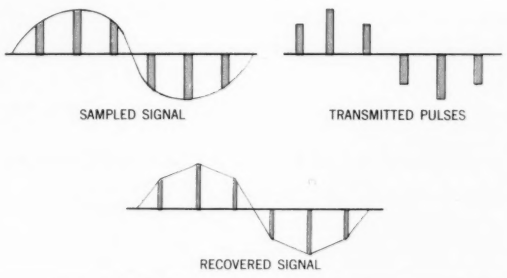

Figure 11 Multiplex Principles

signal. Since we do not want the carrier minus the modulating signal to be lower than 4 KC, our carrier must be at least twice the maximum signal frequency. In effect, the pulse repetition frequency must be at least 8 KC for a 4 KC signal — which is to say that we must sample a signal at least 8000 times per second. One concept is that each half-cycle requires 2 samples, thus resulting in a sampling rate of twice the signal frequency. There are more rigorous concepts, but a mathematical analysis

would further verify the need for a sampling rate of twice signal frequency.

Now that our minimum sampling rate is determined, we must find our minimum sample width in time. If we sampled at a 10 KC rate, or once every 100 microseconds, we could divide this 100 microseconds into one-hundred 1-microsecond time intervals, or "time slots". Since a two-way conversation by this means requires two time slots, 50 conversations could be accommodated on a single transmission medium. If we had components which would permit us to work at higher speeds, we could reduce the sampling width to 500 millimicroseconds and thus put 200 time slots on a single transmission medium.

Let us not forget how much time we are talking about when we mention one microsecond. Light travels about 1 foot in one millimicrosecond, and thus only 1000 feet in one microsecond. When we start pushing half-microsecond pulses around an exchange, the physical size of the office becomes significant from a time standpoint! Nevertheless exchanges are being designed today which use pulses of this length, and when better components become available we will use ever-shorter pulses.

In determining the minimum sampling width, we must consider the system losses which are inherent in this type of system. Since we are sampling a speech wave for only a short period of time, we are recovering only a portion of the original signal; the loss must be recovered within the system itself. This means that it will be necessary to use amplifiers in such a system, but this is not the disadvantage it may seem to be; if amplifiers are used it will be possible to adjust levels of transmission so that a switching stage can be performed without signal loss. It is apparent that as the width of the sample decreases, the power supplied by the amplifier must increase.

Typical Systems

Several approaches can be taken in building time-division-multiplex systems. First let us consider a small P-A-X such as shown in Figure 12, which has 4 lines conected to a common *highway* (shown in color) by means of 2-way gates. The common highway in this case is a single conductor, and the gates permit transmission in either direction. The links are connected to the common highway by similar gates — one link being required for each conversation. In a small system of this type, each line can have its own time slot assignment.

In operation, the memory of the control circuitry *remembers* that line A is talking to line B. Line A is gated to the common highway in its assigned time slot. Simultaneously an idle link is also gated to the highway, and a *sample* from Line A is transmitted into the link and temporarily stored. When the time slot of line B comes up it is gated to the highway and the link is again gated to the highway. Thus, during this second time slot, the sample stored in the link is transmitted to line B. This same process is, of course, occuring on a 2-way basis (from line B to line A, also). The function of the control system is to *remember* that line A and line B are talking together, and to send appropriate controlling pulses to the line gates at the proper time. In this case the function of signaling is to set information into the

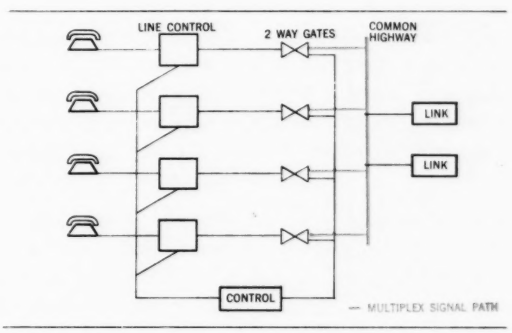

Figure 12. Time-Division-Multiplex System

memory in the proper manner. The bulk of the equipment in a system of this type consists of the line gates, which really are quite simple electrically. Since these can be made quite inexpensively, using printed-circuit techniques and solid-state circuitry, the outlook for this type of system is very good.

Since most telephone men will be interested in something more than a small P-A-X, let us now consider how we can build larger exchanges of this type, which have been in planning stages for several years. Mr. L. R. F. Harris, of the British Post Office Research Branch, published a paper in 1956 which proposed a concept known as a *Switched Highways* system. Basically this concept is the same as shown in Figure 12 for a single line group; in the expanded system, however, time slots are assigned to the "group common highways" as shown in Figure 13, and matched to the line group highways on a synchronized-pulse basis. The lines transmit audio to the associated line-group gates; at the gates the audio is sampled as pulses and placed in the group

common highway. Transmission to another line in the same group would normally create no additional problems over the single-group system previously considered.

Each group is connected to every other group by a highway, containing gates for each group in the system. If a line in Group 1 calls a line in Group 3, the system common control must find an idle time slot on each of the two group common highways, and close the gates between them in these time slots. In this manner a pair of idle time slots in the group common highways become, in effect, a usable trunk circuit between the groups. This could be compared to a 2-wire switching system, since signals are transmitted in both directions on the same signal path.

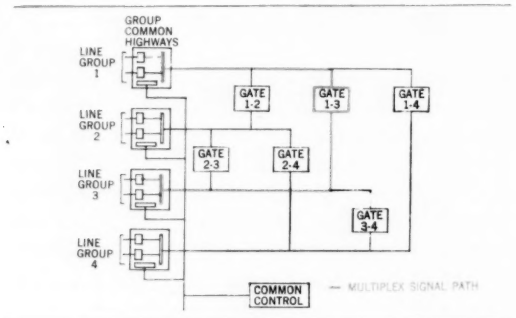

Figure 13. Expanded Multiplex System

Using the *common highway* system it is possible, (and in fact, easier electrically) to provide the equivalent of a 4-wire switching system. This would use 2 common highways in each line group and 2 trunk highways between groups. One advantage of the 4-wire system, in this case, is the ease of making up the losses due to sampling; one disadvantage is the doubling-up of the per-line equipment. Earlier it was mentioned that it might be easier to provide 4-wire systems using electronic means; this is an example. If by using solid-state circuitry, however, we can make line gates more economically, we could very easily provide a 4-wire system—and we must all be aware of the growing trend toward 4-wire operation. It is true that we can build the 2-way common highway using fewer components, but at least this technique lends itself to 4-wire operation more easily than some existing systems.

Let us now briefly compare crosspoint and time-division-multiplex techniques, as far as 4-wire switching is concerned. The multiplex uses an extremely simple transmission system at the expense of gate equipment individual to each line. The crosspoint technique uses a much simpler line circuit but requires large amounts of equipment in the transmission network.

Some Multiplex Problems

One of the problems in multiplex operation is crosstalk. The telephone man who has struggled with crosstalk in audio circuits may feel that it is quite a problem, but when you compare the 4 KC audio channel with a control system operating at one megacycle or higher frequencies in a multiplex exchange, you might appreciate the relative insignificance of present crosstalk problems. We visualize as being completely intolerable, for example, the present practice of bunching wires together in a cable. The use of printed-circuit techniques or something similar makes our problems easier, since we can control the relative location of our conductors. Please note that I said *conductors* and not "wires"; we visualize future exchanges without wires, other than the entrance cables. This is a startling concept of construction, but one which will help considerably in controlling these high frequencies — and of course it will lend itself to complete fabrication in the factory by automatic insertion machinery.

Time is another problem associated with the multiplex exchange. Earlier it was mentioned that we are concerned with the amount of time it takes to get a pulse from one part of the exchange to another. Perhaps it may be easier to visualize this when you consider the trunk highways of a multiplex system. If the system common control of Figure 13 should send a pulse simultaneously to the gates of Line Groups 1 and 2, it could happen that, due to the physical size of the office, the pulse would arrive at Line Gate 1 sooner than it would at Line Gate 2. The net effect would be that the actual connection between these groups would exist for a much shorter period, during that time interval, than is required for an adequate transmission level. Perhaps the periods might overlap into an adjacent time slot. Obviously something must be done to compensate for such differences. Circuit designers can build-in deliberate delays as required, and the nature of the transmission medium from Group 1 to 2 will also be significant — for example, coaxial cable has been used for this purpose. This would

tend to suggest an exchange which would consist of small modular line groups and sub-groups connected together by coaxial cable.

There is an alternative solution to this problem of timing on interstage coupling. The system shown in Figure 14 would not be bothered by such time considerations, but it would require considerably more equipment. Basically this system consists of a combination of line groups in which signals are reduced to audio for inter-group trunking. A system of this type could almost be considered a step-by-step system. Each line group would consist of a multiplex highway, with trunks to other groups on an audio basis. The conversion to audio in this manner is relatively expensive and undesirable, but it may offer possibilities. Control on this basis would be from stage to stage to the called line, with the common control of each stage sending routing information forward to subsequent switching stages. It would seem that despite its inherent disadvantage of conversion to audio, this system would come closer than others to providing the tremendous flexibility and convenience of growth of our present Strowger system.

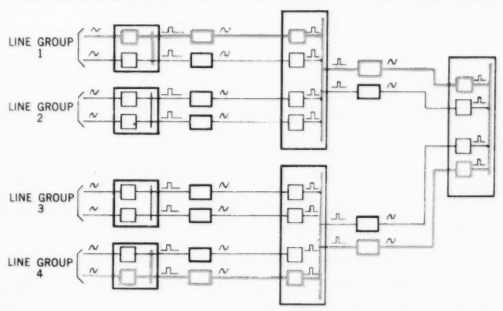

Figure 14. Expanded Multiplex System Audio Trunking

Now that we have briefly considered two basic types — "crosspoint" and "time-division-multiplex" — of electronic switching systems, let us return, for a few moments, to the subject of memory.

As previously mentioned, some type of "memory" seems to be essential for electronic switching; in fact, two "memories" are necessary—a "temporary" memory and a "permanent" memory.

Temporary Memory Systems

The temporary memory is that which is required to be changed one or more times during the processing of a call. Digit registers, line-condition indicators, and the transmission network control are examples of temporary memory. We must make a distinction between temporary memory of the type just described and the normal wired logic memories which form the backbone of the control system. A *flip-flop* circuit is really a bit of temporary memory, and it may be used for any of the functions just described. However, it is not usually considered to be a "bulk" memory cell or one which is grouped together with others in a large group of cells.

In a permanent memory each cell assumes a definite condition for a given length of time, under manual control; this means that the permanent memory is not changed, except under manual control. Typical applications of this type of memory would be network location of a given terminal, party assignment on a party line, ringing-frequency assignment, rate information, route information, and alternate route information.

Most forms of temporary memory can be used as a permanent memory, although those which require continuous excitation or power are not particularly well suited for use as a long-term or permanent memory.

Magnetic Tape

One of the earliest forms of electronic memory was the magnetic tape, which is particularly well suited to storage of data that can be read out serially. It is unsuited, however, for control of switching circuits, because it cannot easily access any desired bit of information. This is not to say that we should disregard tape storage; this form of memory is in wide use today—in fact, there is probably no better storage medium presently available for serial-type information. It may be used, for example, for input and output of data-transmission systems in connection with telephone exchanges—and with the ever-increasing importance of data transmission systems, we may expect that tape storage will play an important role in the future.

Magnetic Drum

Another type of memory, which is similar to tape but permits rapid access, is the magnetic drum. The drum was first introduced in the computer field and is still being used for that purpose. Since a spot on a

drum can hold its polarity sufficiently long, it can be considered a permanent memory.

One advantage of the magnetic drum for switching is its low initial cost per bit; and of the techniques which have been used to date it is probably the cheapest. One disadvantage, however, is that the magnetic drum, since it is rotating machinery, requires maintenance; this is a disturbing thought in a plan which visualizes an exchange that will never require maintenance. The Lee Green exchange of suburban London, England, uses a magnetic drum register translator in a Strowger system.* One magnetic drum is adequate for the entire exchange. A further use for a magnetic drum is in the field of subscriber metering of toll calls. The assignment of a few spots per subscriber is not expensive and it provides an immediate access for billing which can be removed on page copy, or on punched tape for automatic processing. In fully electronic systems the magnetic drum can be used as a permanent memory, but its limited access time precludes its use for control purposes in a multiplex system.

Ferrite Core

Ferrite cores are another form of magnetic memory which have possibilities as memory cells. These devices, sometimes as small as .050 inches in outside diameter, use the square hysteresis loop characteristic as a memory. Because these memory cells are small and easily controlled, and are completely static, they are attractive to use as memory cells. They can be switched sufficiently fast to be used as temporary memories in a time-division-multiplex system. However, one disadvantage of ferrite cores lies in the relatively large driving currents which they require. At the present time the cost of a ferrite core memory system is considered to be too high for large scale permanent memory in a telephone system. As a temporary memory they offer great possibilities.

Barrier Grid Storage Tube

Several applications have been found for this type of temporary memory, shown in Figure 15. The tube consists of a cathode gun, deflection plate and grids, a target plate which is constructed in the form of thousands of tiny capacitors, and a back plate. The electron stream (shown in color) is directed to a particular one of these capacitors. As the electrons strike the target plate, a discharged cell will assume a charge, and electron flow to accomplish this will be recorded. Thus a spot is either charged or discharged as a "yes" or "no" answer, and each tiny capacitor corresponds to the memory function of one relay. The control circuitry for this memory is rather conventional and well known, and electrostatic memories similar to this technique have been used for several years. Tubes of this type are being designed into several telephone systems today.

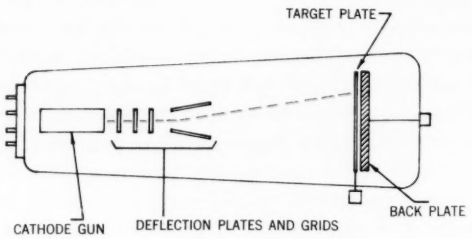

Figure 15. Barrier Grid Storage Tube

Delay Line

This is another form of temporary memory which may be used in exchanges of the future. The delay line shown in Figure 16, is of the magnetostrictive type, which makes use of the property of nickel wire wound around nickel tubing or wire to transmit a shock wave over its length. In a line of this type a pulse is introduced into a transducer at one end of the nickel wire; the coil introduces a mechanical shock in the wire which travels down the length of the wire at approximately the speed of sound. At the other end, this pulse is recovered by a transducer and converted back to an electrical pulse; it can be used and compared in time phase with the original pulse. A portion of the output pulse can be fed back into the input and started down the line again; in this way the pulse can be recirculated in a time phase relationship to the originating pulse. This technique can be used as a memory and by looking at the output at any particular time interval we can determine whether there is an output pulse at that time. A delay line of this type, approximately 3.7 inches long, will store 10 pulses each 2 micro-

**Design Features of the Lee Green Magnetic Drum Register-Translator, The Post Office Electrical Engineers Journal, Vol. 51, Part 2, July, 1958.*

seconds in length, and it can be used to store the 10 impulses of a dialed pulse train. A delay line of 100 microseconds in length could be used to control a time-division-multiplex common highway by allocating 50 different conversations to 100 time slots of one microsecond each. Whether the delay line is used for memory in this way, or whether it is used only for general logical control circuitry, it promises to be a very useful tool in almost any type of electronic exchange.

These are but a few of the many possible types of temporary memory. As our familiarity with electronic techniques in switching increases we may find other forms of temporary memory which are not known today.

Permanent Memory Systems

We can turn now to a consideration of permanent memory systems. As we have previously mentioned, several of the forms of temporary memory

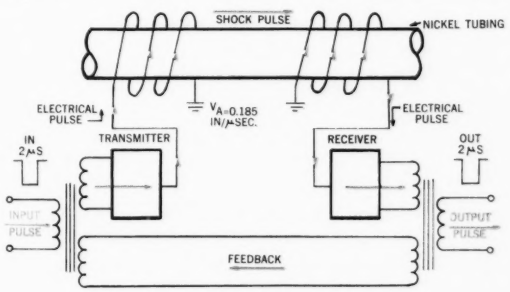

Figure 16. Delay Line Data Storage, Magnetostriction Principle

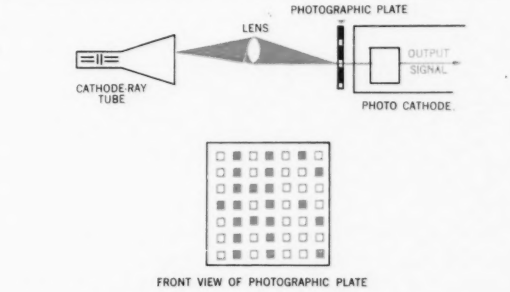

Figure 17. Flying Spot Store

can also be used as a permanent memory. The magnetic drum is well suited as a permanent memory, but its access time and maintenance requirement make it rather unattractive. The ferrite core could be used also, but is rather expensive for use in a major permanent memory.

One form of permanent memory known as the *flying spot store** is illustrated in Figure 17. It consists of a photographically made plate on which each spot location is either dark or transparent, depending on what is desired. A beam of light from a cathode ray tube is directed to the spot, and it is either blocked or is permitted to pass through the plate. If it passes through it falls on a photo cathode which emits electrons that are drawn off in the external circuit as a signal.

The tube's deflection system directs the spot to a particular location; the spot of light is then picked up optically and focussed on the particular bit on the plate which must be read out. It would seem that the idea of using a photographic plate for the permanent memory affords a means of supplying a very large number of bits; however, the circuitry required to control the spot is very complex, and the optical system must be very precise. In this system any one of several million bits of memory can be accessed in a matter of a few microseconds.

Another technique of memory which is being considered in several research laboratories is the use of extremely low temperatures to control conductivity. This technique makes use of the fact that the resistivity of certain materials reduces to zero at a temperature of approximately 4° Kelvin (approximately —450°F.) or that of liquid helium. It has been found that if a conductor with zero resistivity is placed in a magnetic field its resistivity will be increased to a definite value, such that the difference can be detected as a "yes" or "no" signal. Obviously, then, a small conductor can be wound with a coil of wire and reduced to about 4° Kelvin. By controlling the current through the coil we have a memory cell. It is believed that such cells offer great promise as either temporary or permanent memories, and also as logical-control circuitry.

An Experimental Switching System Using New Electronic Techniques, Bell System Technical Journal, Volume XXXVII, September, 1958.

Some telephone men would recoil at the thought of operating exchanges at nearly 450° below zero Fahrenheit, but it appears to be within the realm of practicality.

Digital Transmission

We can now turn our attention to the field of Digital Transmission, which is a little farther over the horizon than the systems which I have been discussing up to this time. We know that the volume of digital transmission is increasing, and there seems to be an ever-increasing demand for the transfer of large quantities of data from one point to another. The increased use of centralized data-processing by business and industry has indicated the trends for the future, and we believe that we have just scratched the surface of this type of communication —in fact, it is probable that the volume of data transmission may one day exceed that of ordinary telephone communication as we know it today. *What will be the impact on our activities of such a concept?*

One of our obvious conclusions is that for all practical purposes we will no longer be telephone companies; it is apparent that we will be involved in all forms of communication, and many new services will be provided for our customers. But what type of switching system will we use for all of these communication services?

First, let's consider data of the type which is used in most business and industry—data transmitted in digital form. At the present time, such data are transmitted primarily by interruption of a modulated carrier signal, or by shift of modulating signal frequency. Since this is the same form as audio, the data can be put on standard telephone channels. But why should we transmit it in this way? Why can't we transmit the pulses directly over the circuit instead of using them to modulate a carrier signal? The answer is, we can, and this may become the next step in data transmission. Up to this time it has been considered that pulse transmission on cables was impractical, due to high attenuation and signal distortion. With the possibility in the future of inexpensive, transistorized, regenerative repeaters, it may become practical to employ this type of transmission. In pulse transmission the signal-to-noise ratio is less important than in audio transmission, because as long as the presence of a signal can be detected at all, the regenerative repeater can retransmit it easily as a perfect signal. The Bell System recently published*reports of their experiments using pulse-code transmission on an exchange trunk carrier. It appears that this method is very satisfactory over existing cables. For the present we need merely remember that data can be transmitted over telephone channels on a pulse basis.

Now let us go one step further. If we are to provide pulse carrier systems, why can't we transmit audio on this basis also? We can! We have already discussed how audio can be reduced to a train of pulses in pulse amplitude modulation. Now we shall consider how it can be transmitted in pulse code modulation.

Pulse Code Modulation

Figure 18 shows how an audio signal can be encoded in a pulse code modulating system. The chart numbers show the maximum signal divided into 7 equal increments.

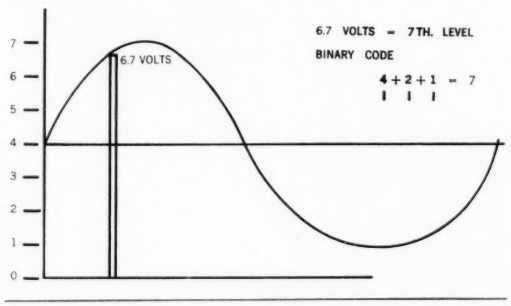

Figure 18. Pulse Code Modulation Encoding Plan

By dividing the maximum sample into several equal-valued increments, we can define any sample to the nearest multiple of that increment. For example, a 6.7-volt sample can be defined as nearly equal to *seven* one-volt increments. The number *seven* can then be stated in binary code as 111. The first pulse has a "weight" of $2^2=4$, the second pulse has a "weight" of $2^1=2$, and the third pulse has a "weight" of $2^0=1$.

In transmission, each sample is represented by presence or absence of these binary code pulses. The receiver detects the presence of the pulse during given time intervals and reconstructs the original

**Transmission Applications, Bell Laboratories Record, June 1958.*

sample by summing the "weight" of each received pulse. When *no* pulse is received during the interval, nothing is added to the reconstructed sample.

The principal advantage of PCM is that it operates well, even for low signal-to-noise ratios. Since we are not transmitting an amplitude or pulse width directly, we merely detect whether the signal at a given instant is above or below the threshold, so that the receiver may determine whether a pulse was transmitted. The signal-to-noise ratio may be as low as 15 db without any significant distortion.

For good quality audio transmission, a bandwidth of 40 KC is required for each 4 KC voice channel; this is a disadvantage of PCM. This wide bandwidth is required because acceptable reproduction requires at least 32 increments, which in turn are coded by 5 pulses. If we sample 8000 times per second and provide 5 pulses per sample, we must transmit 40,000 pulses per second for each 4 KC voice channel.

Delta Modulation

Delta modulation is similar in many respects to PCM. Instead of coding each sample independently, however, we code only the *difference* between the amplitude of a sample, and that of the previous sample. In its simplest form, the Delta code consists merely of one pulse for a sample of higher amplitude, and *no* pulse for one of lower amplitude. At the receiver, one voltage increment is *added* to the previous sample if a pulse is received. One increment is *substracted* if no pulse is received.

Like PCM, delta modulation can operate with a low signal-to-noise ratio requirement. It is generally less expensive than PCM but has somewhat poorer quality reproduction characteristics for the same 40 KC bandwidth.

It should be noted that both PCM and delta modulation techniques can be used on narrower bandwidth channels when the line noise is low. For example, we can allow each pulse to have two amplitudes, thereby reducing the bandwidth to 24 KC. That is, a full pulse could have a "weight" of 2, and a half-pulse a "weight" of 1. The second full pulse would have a "weight" of 6. If the second pulse were only half amplitude, its "weight" would be 3. The three-pulse code in this case would supply 27 levels which is nearly equal to the 32 level nominal requirement. Signal-to-noise ratio would have to be double the previous value, however. In general, bandwidth can be "traded" for lower signal-to-noise requirements on a logarithmic basis, rather than the direct basis of sinusoidal modulation techniques.

We can now visualize how speech can be transmitted in digital form. Our next step appears to be quite logical. *If speech and data can both be transmitted in pulse form, why can't we transmit them both in the same form?* This then visualizes a transmission medium which will transmit either type of information on an indiscriminate basis. Once we have established the principle of transmission between two points on this basis, the next question would be directed toward the switching system which will handle either data or speech without realizing the difference. Such a system has been under consideration by the government for military applications.* It may be in our future also.

Conclusion

The telephone company of today is on the verge of an exciting new era in providing communication facilities and services. Many of these must come about through a basic change in call-handling techniques. It seems almost certain, in view of the tremendous strides being made in electronics, that this change will be in the direction of electronic switching.

Many studies have been made in this field, and some of them have shown great promise. It is safe to say that a completely practical electronic means of switching telephone calls and communication circuits will be developed. We suffer, however, from an embarrassment of riches; there are so many ways this development might lead that we will not for some time know even the direction that will be most promising. In this article we have touched on some of the problems faced in this field, and some of the concepts that seem to offer a solution to these problems.

It may be a long time before public telephone exchanges will be operated electronically, on any other than an experimental basis. But we know that day *will* come—and progressive telephone men will be ready for it!

*"*Futuristic Military Communication System,*" Signal Magazine, August, 1958.*

CONTROL OF IMPURITIES IN SEMICONDUCTOR CRYSTALS

By Thomas A. Longo, Senior Project Engineer, General Telephone Laboratories, Inc.

The properties of single-crystal semiconductor materials are extremely sensitive to crystalline imperfection. To secure improved quality in these crystals, General Telephone Laboratories has recently adapted techniques which provide closer control over these imperfections.

The methods of growing large single crystals involve melting polycrystalline material, and then using a single crystal seed to nucleate the recrystallization of the molten material. There are two common types of crystalline imperfections—chemical impurities and mechanical defects. Mechanical defects are known as dislocations (resulting from the improper positioning of the host atoms in the crystal lattice). Both types of imperfections are introduced into the semiconductors during the growing process; chemical impurities are not necessarily undesirable.

It is the ability to introduce certain chemical impurities into the semiconductor in a pre-planned manner, which allows the technologist to control the electrical properties of the semiconductor materials. At the same time every effort is made to prevent the introduction of undesirable impurities.

One such undesirable impurity which is extremely troublesome in silicon is oxygen. In recent years it was discovered that drastic changes in the properties of single-crystal silicon which occurred with heat treatment during the processing of silicon crystals were linked with the presence of oxygen in the silicon crystal lattice. Of course it was immediately recognized that the oxygen was introduced into the molten silicon during the growing process. This results from the fact that the quartz crucible, of which oxygen is a main constituent, is slowly dissolved by molten silicon.

A crystal-growing technique which minimizes the introduction of the oxygen impurity in the growing single-crystal is now being used at General Telephone Laboratories. This technique, as illustrated in Figure 1, involves the rotation of the crucible in the same direction and at the same speed as the seed crystal. This effectively results in what has often

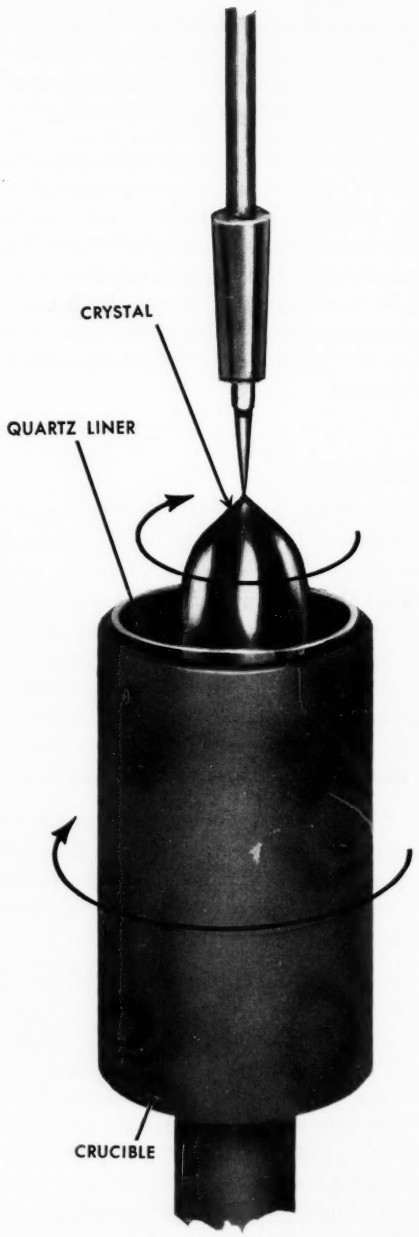

Figure 1. Crystal-Growing Technique showing rotation of Crucible in same direction as Seed Crystal.

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been called a *non-rotated* crystal. Such a crystal is found, by a study of the silicon infrared light transmission characteristics, to contain much less oxygen than a crystal which is grown while only the seed crystal is rotated. The number of oxygen impurities in a *rotated* crystal is greater than one part in a million, whereas the number of such impurities in a so-called *non-rotated* crystal is of the order of one part in ten million. Crucible rotation also gives a better heat distribution in the melt, which in turn permits better control of the shape of the growing crystal.

Dislocations in device materials interfere with some of the succeeding processing techniques, and in many devices, large densities of dislocations will lead to inferior operating characteristics. The technique used by Laboratories to minimize this difficulty is that of "necking down" the silicon seed crystal to a very small diameter (as shown in Figure 1) before expanding it into the large-diameter single-crystal. A few investigators[1] in other laboratories have observed that similar procedures reduce the number of dislocations introduced during the growth process.

Another technique recently adopted by Laboratories assures a greater degree of uniformity in the amount of impurities throughout a single-crystal. As indicated earlier, the electrical properties of the materials are determined by the controlled introduction of chemical impurities in the semiconductor crystals. For most applications, the desired impurities are introduced into the molten semiconductor material before the crystal is grown. However, as the semiconductor material is recrystallized from the molten material containing the added impurities, it is found that the relative amounts of impurity and semiconductor leaving the molten phase and entering the solid phase do not remain constant. In fact, most impurities prefer to remain in the molten phase. The result is that as the crystal-growing proceeds and the volume of the melt decreases, the concentration of impurities in the melt increases strongly. This, in turn, leads to a strong gradient of chemical-impurity concentration in the grown crystal, such that the bottom of the crystal is often more than ten times more impure than the top of the crystal. This effect reduces considerably the yield of usable material in conventionally grown single-crystals.

Recently a technique known as the *floating-crucible* method has been developed[2] to eliminate the strong impurity gradient in grown crystals. Figure 2 shows the adaptation of this floating-crucible technique which is being used at General Telephone Laboratories in its germanium crystal growing operations. There is an inner quartz crucible resting in an outer graphite crucible; this inner crucible has a hole in the bottom, allowing molten germanium contained in the outer crucible to enter. Therefore as the single-crystal is grown from the melt contained in the inner crucible, the outer crucible acts as a reservoir of molten germanium. This *reservoir* function of the outer crucible serves to keep the volume of molten germanium constant in the inner crucible. The desired impurities are added to the inner crucible only, and since the volume of the melt remains constant in this inner crucible, the relative amounts of impurity and germanium solidifying into the single-crystal remain constant. The net result of this process is that large crystals of germanium can be grown with reasonably constant impurity concentration over most of the length of each single-crystal. In this way the percentage yield of usable material per grown crystal can be increased three- or four-fold from the more conventional previously used technique.

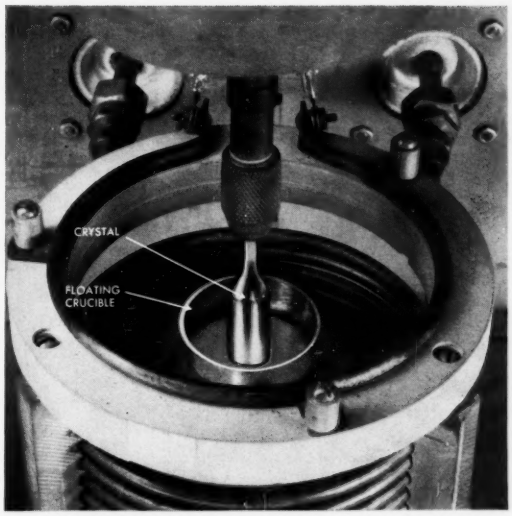

Figure 2. Floating-Crucible method showing Inner Quartz Crucible resting in an outer Graphite Crucible.

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[1] *H. J. Yearian, Purdue University, Private Communications*

[2] *W. F. Leverton, J. App. Phys., 29, 1241, 1958*

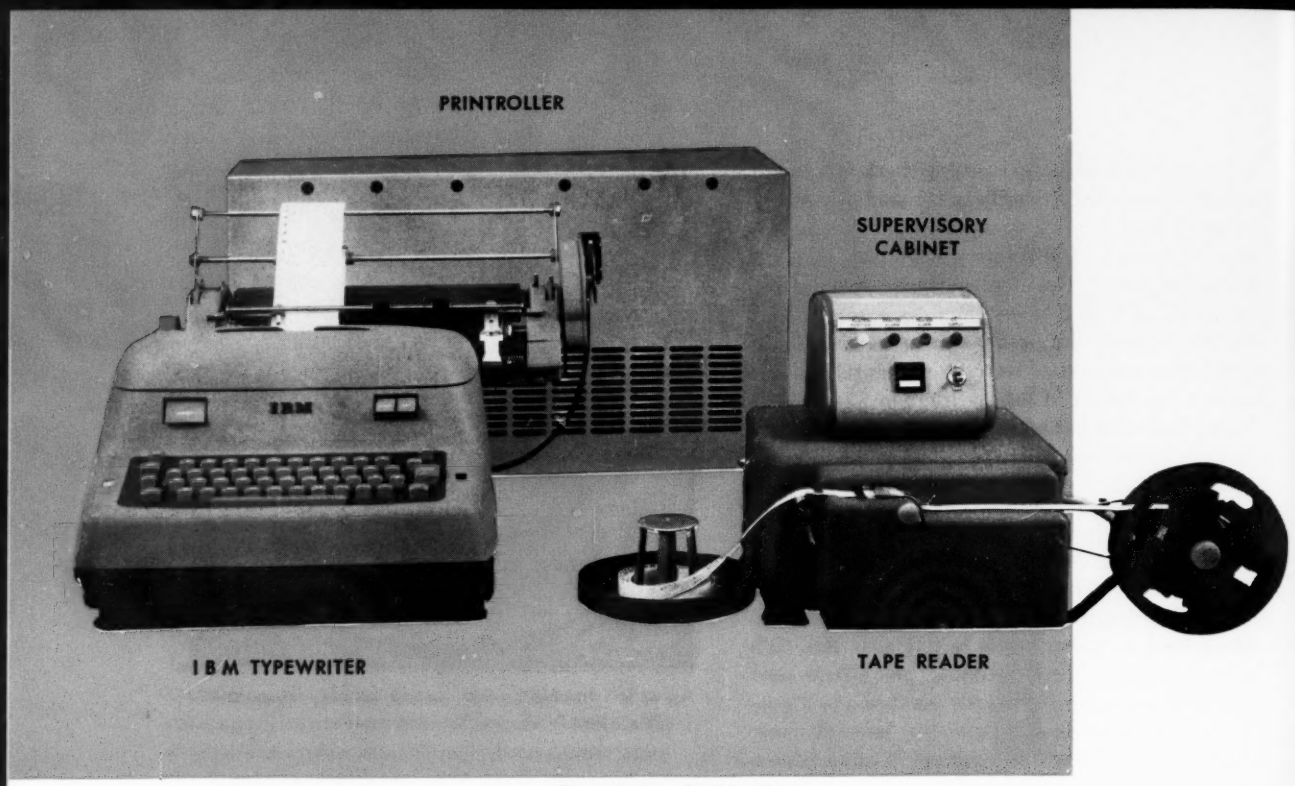

Figure 1. Type 57 Ticket Printer

NEW SATT TICKET PRINTER

By Robert G. O'Neill: General Telephone Laboratories, Inc.

In all Strowger Automatic Toll Ticketing (SATT) systems, customer-dialed completed toll messages are recorded on a four-channel (or five-channel) punched paper tape. This tape can be used to automatically produce punched cards for business machines—or to produce typed, standard-size, toll tickets where business machines are not available in the accounting department.

This article describes the new Type 57 Ticket Printer currently supplied for SATT installations which require conversion of SATT tapes into regular 5″ x 2½″ toll tickets. The Ticket Printer is a special IBM electric typewriter with associated control units, as shown in Figure 1. A typical preprinted toll ticket, and a sample of the punched paper tape, are shown in Figure 2. The toll ticket, made of high grade paper stock, is suitable for microfilming, if required.

The ticket contains the usual data required for billing purposes; however, points of origin and destination are recorded in numerical code rather than exchange name, or office code. The seventh line (Ticketer, Tabulator) permits tracing the information recorded on the ticket to specific equipment units; this is for maintenance, not for accounting purposes.

The toll charge will appear in typed form only where automatic rating of tickets is provided for by means of an A.E. toll-charge computer. Small installations may not always warrant the initial use of such a computer; in such cases, the "toll charge" line will be blank, and the SATT tickets will require manual rating exactly as other manually prepared tickets.

The Type 57 Ticket Printer is made up of 4 separate components:

TAPE READER: converts the perforated toll tape "codel" code into a decimal form so that it can be handled by conventional relays and stepping switches.

PRINTROLLER: consists of Automatic Electric Company relays and rotary switch equipment, and provides the link between the coded information from the tape reader and the printed toll ticket.

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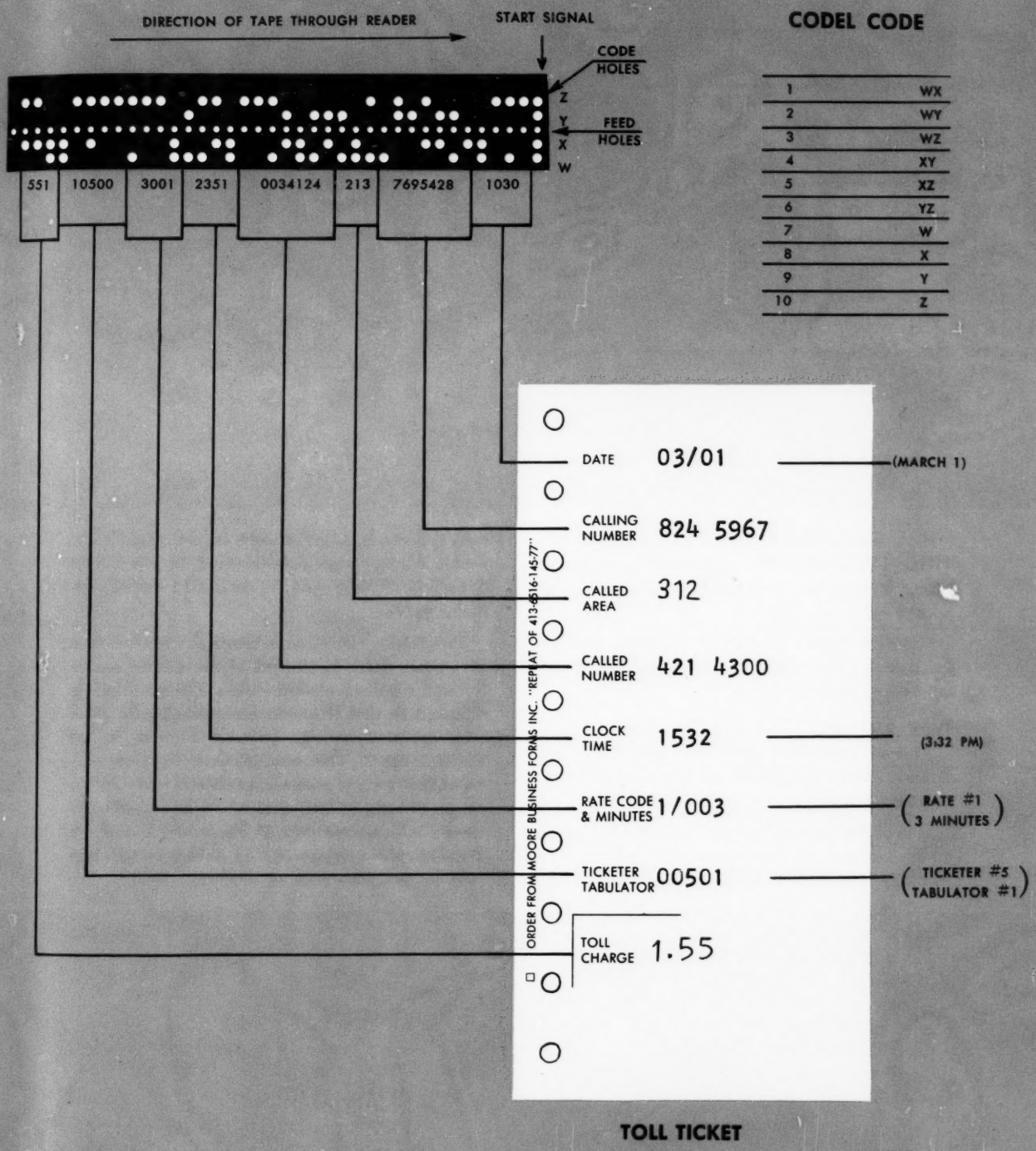


Figure 2. Typical Perforated Toll Tape and Ticket

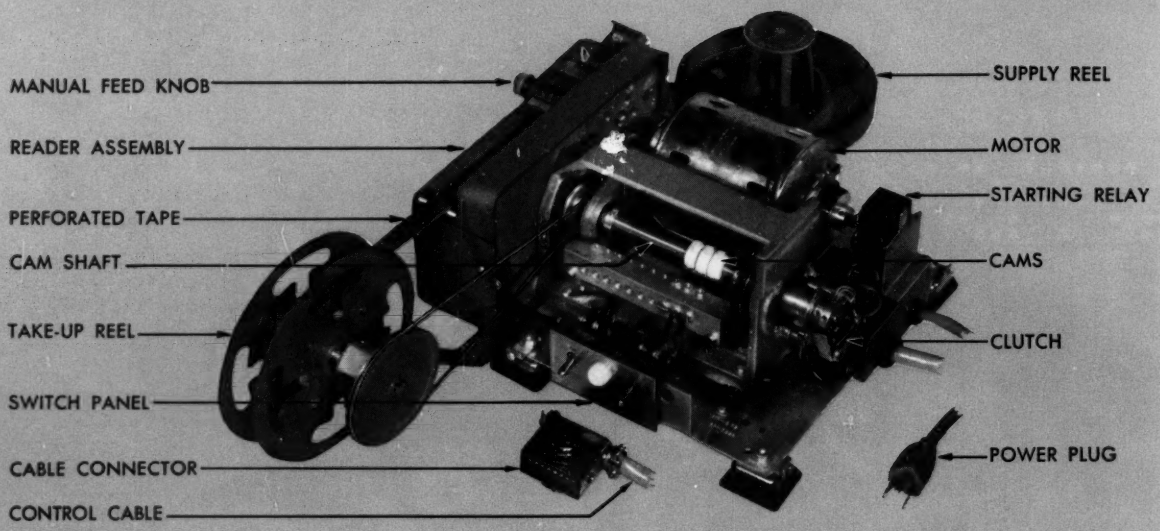


Figure 3. Tape Reader (Top View)

IBM REMOTELY CONTROLLED ELECTRIC TYPEWRITER: automatically types the billing information for each toll call onto a preprinted toll ticket.

SUPERVISORY CABINET: provides facilities for metering the ticket count, and for alarm and supervisory signals.

Tape Reader

This unit, known as the Friden Motorized Tape Reader, Model 2, is shown in Figures 3 and 4 with its cover removed.

It is of the pin-sensing type, each pin having an associated pair of "code contacts" which close when the appropriate pin is up (i.e., when it protrudes through a perforation in the tape being read). Where no perforation exists the pin is held down by the tape and the associated contact remains open.

The reader operation is under the control of a cam shaft which is coupled to the driving motor through a half-revolution clutch. The cam shaft is designed so that the code contacts are always in their operated position between impulses to the clutch magnet. This arrangement, together with an auxiliary set of cam shaft contacts wired to the reader switch, insures that when turned off, the reader will always stop at its full-cycle position (sensing pins withdrawn) so that message tape may be easily inserted or removed.

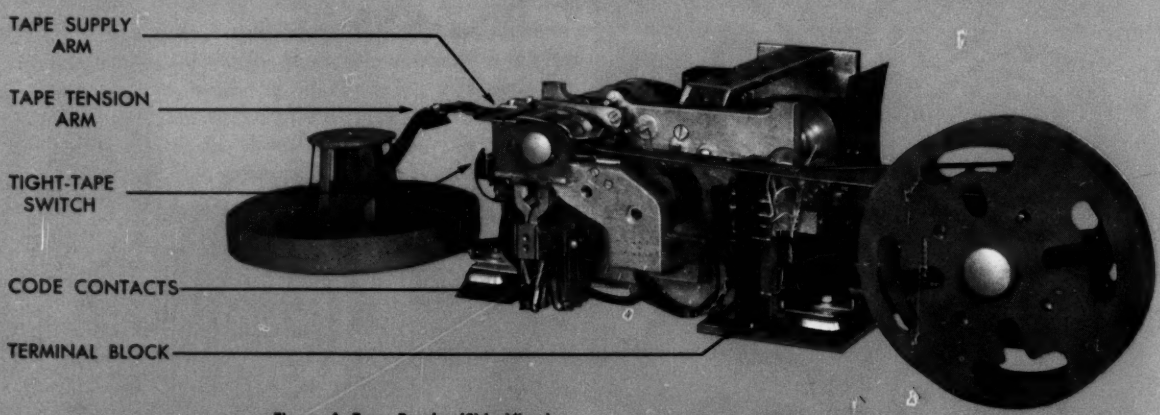


Figure 4. Tape Reader (Side View)

Two other auxiliary sets of cam shaft contacts are also provided, one for start-of-cycle control, and the other for spark protection. Figure 5 shows the timing relationship between these contacts for a full cycle. Other contacts are provided which, when wired into appropriate circuits, produce alarm signals for either tight tape, out of tape, or tape not in proper feeding position.

The reader is powered with a one-thirtieth horsepower, 115-volt, 60-cycle induction motor, operating at 1200 r.p.m. It is equipped with a small motor-starting relay and protected by a 2 ampere time-delay fuse. A small V-belt is used to couple the cam shaft to the motor. The takeup reel is driven from the cam shaft by means of a spring belt and step-down pulley. The reduction is such that the reel will keep pace with the flow of message tape, winding it up as it is fed from the reader. The tape unwinder is a spool upon which the coil of perforated message tape is placed to hold it in position as it is pulled into the reader by means of feed holes which are engaged by the reader feed sprocket.

Overall dimensions of the reader are: length 25″, width 13″, height 6½″.

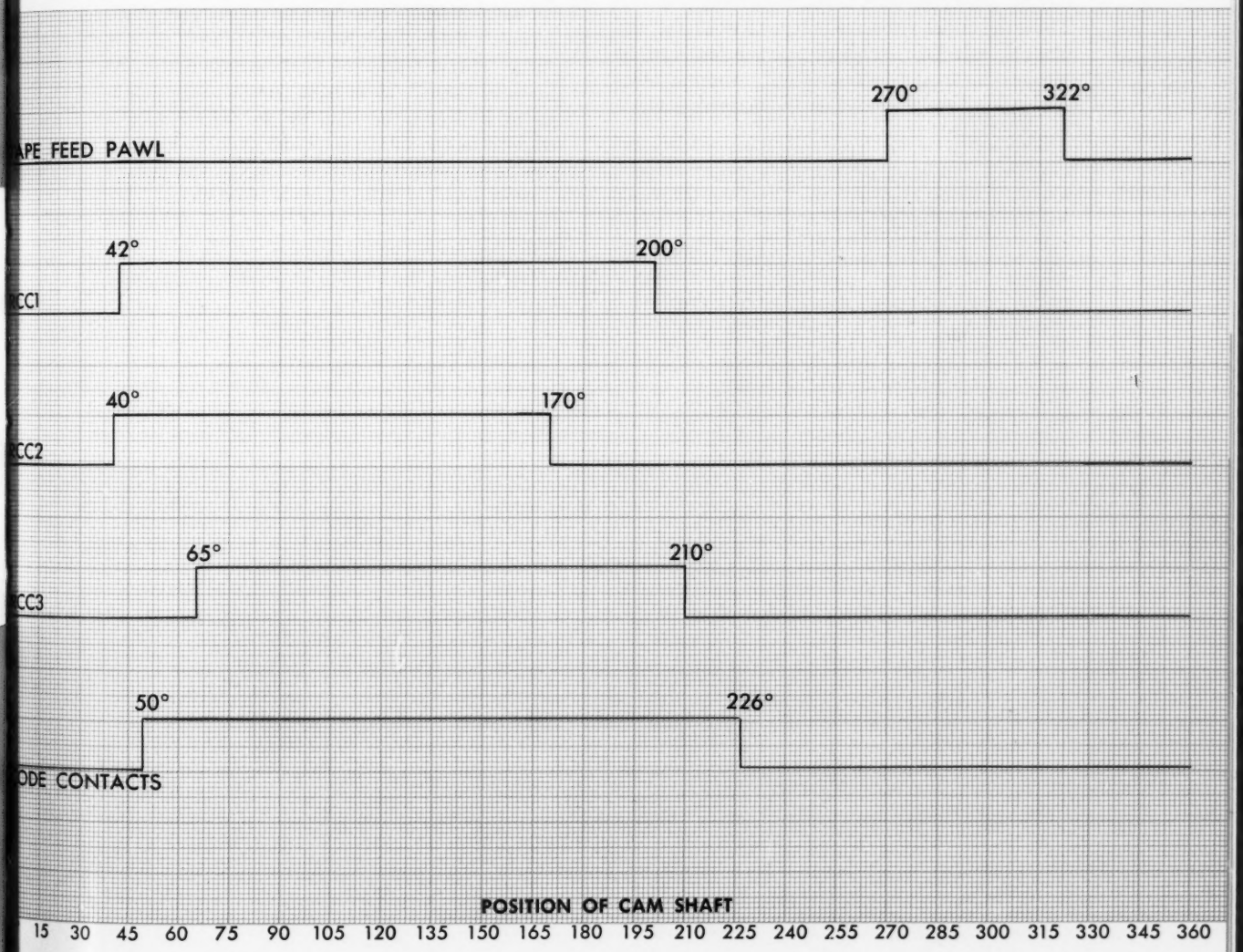


Figure 5. Timing Chart Showing Relation Between Contacts for Full Cycle

Printroller

This is the main control circuit, consisting of Automatic Electric relays and rotary switch equipment. Figures 6 and 7 show the compact, efficient manner in which the relays are mounted on a sturdy steel framework, together with the shock-mounted rotary switches. Cable connectors lock into the control jacks, eliminating any possibility of loose cable connections. Also shown is the heavy-duty, constant-voltage, 48 volt DC power supply which supplies well regulated, filtered direct current for operation of the relays, switches, and other DC operated components of the printer. This DC power supply operates directly from the commercial AC lines (the same as the reader and printer). Thus, the entire system is independent of the regular 48 volt DC exchange voltage and can be plugged in at any location in the business office convenient for the processing of the message tapes.

Bank contacts of the two rotary switches are multipled together and wired to the terminal block for control strapping as required by the telephone company. Strapping necessary to produce a typical toll ticket, as shown in Figure 1, would follow the arrangement shown in Table A. The message is printed on 8 lines of the toll ticket; since each ticket has a total of 10 lines, three successive carriage returns (abbreviated "CR" in Table A) at the end of the message correctly position the ticket paper for the succeeding message. (If the size of the office does not warrant the use of a computer, and the toll charges are not to be printed, four successive carriage returns are required at the end of each message. The rotary switch bank terminal strapping will then be modified for terminal B45-B50 and C1-C4 shown in Table B.)

If the equipment identities (identifying numbers showing which ticketer and which tabulator were used in recording the call) are not required, then the rotary switches will be strapped to produce 5 successive carriage returns. The release and alarm controls (abbreviated RLS and AL in Tables A and B) always follow the final carriage return. As shown in Table A, every bank terminal corresponding to a digit to be read by the tape reader is strapped to the TR (tape reader) control contact. The bank contacts corresponding to the printer controls such as CR (carriage return), ST (stroke), SP (space) and DT (dot) are strapped to the respective control terminals as required. The strapping may be modified to produce any desired sequence of information.

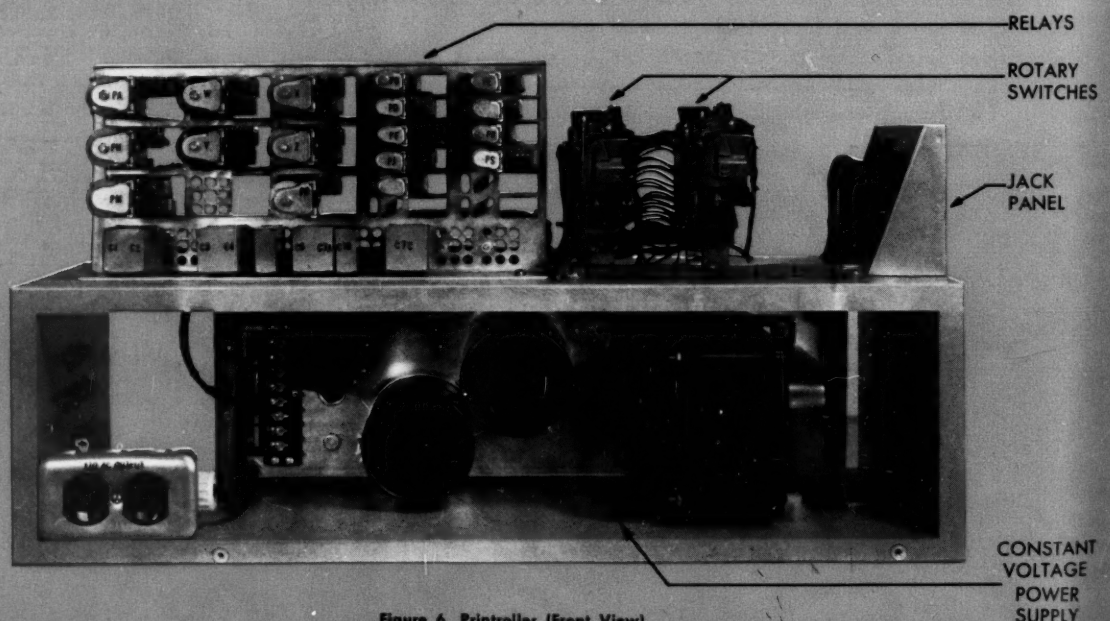


Figure 6. Printroller (Front View)

TABLE A			
FUNCTION		STRAP ROTARY SW TERMINAL	TO CONTROL TERMINAL
DATE	MONTH	A1 A2	TR TR
	STROKE	A3	ST
	DAY	A4 A5	TR TR
CARRIAGE RETURN		A6	CR
CALLING NUMBER	OFFICE CODE	A7 A8 A9	TR TR TR
	SPACE	A10	SP
	TERMINAL DIGITS	A11 A12 A13 A14	TR TR TR TR
CARRIAGE RETURN		A15	CR
AREA CODE		A16 A17 A18	TR TR TR
CARRIAGE RETURN		A19	CR
CALLED NUMBER	OFFICE CODE	A20 A21 A22	TR TR TR
	SPACE	A23	SP
	TERMINAL DIGITS	A24 A25 AN B26	TR TR TR TR
CARRIAGE RETURN		B27	CR
TIME OF DAY		B28 B29 B30 B31	TR TR TR TR
CARRIAGE RETURN		B32	CR
DAY OR NIGHT RATE		B33	TR
STROKE		B34	ST
CONVERSATION TIME		B35 B36 B37	TR TR TR
CARRIAGE RETURN		B38	CR
TICKETER NO.		B39 B40 B41	TR TR TR
TABULATOR NO.		B42 B43	TR TR
CARRIAGE RETURN		B44	CR
DOLLARS		B45	TR
DOT		B46	DT
CENTS		B47 B48	TR TR
CARRIAGE RETURN		B49	CR
CARRIAGE RETURN		B50	CR
CARRIAGE RETURN		C1	CR
		C2	
RELEASE		C3	RLS
ALARM		C4	AL

Table A. Strapping Arrangements

TABLE B (otherwise same as Table A)		
CARRIAGE RETURN	B45	CR
CARRIAGE RETURN	B46	CR
CARRIAGE RETURN	B47	CR
	B48	
RELEASE	B49	RLS
ALARM	B50	AL
TERMINALS C1-C4 NOT USED		

Table B. Strapping Arrangements (Modified)

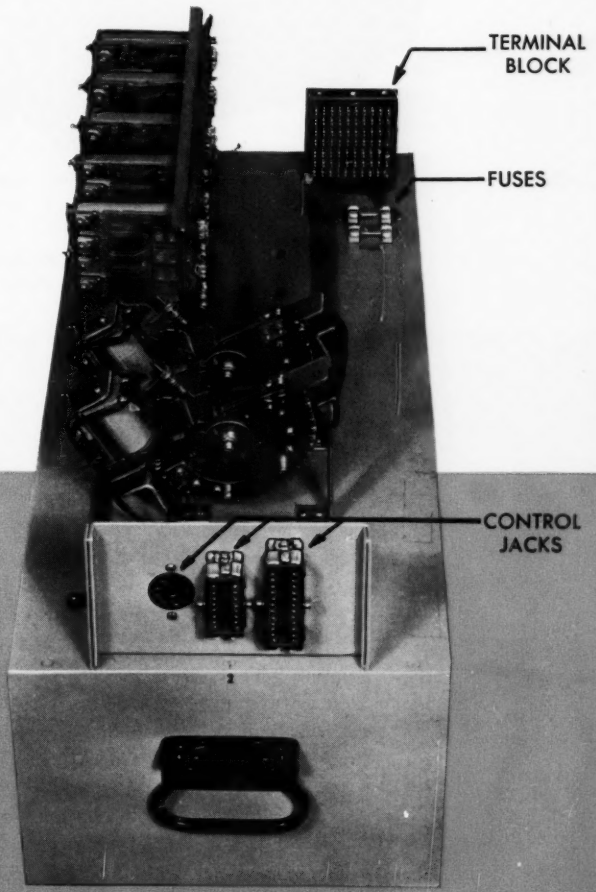


Figure 7. Printroller (Top View)

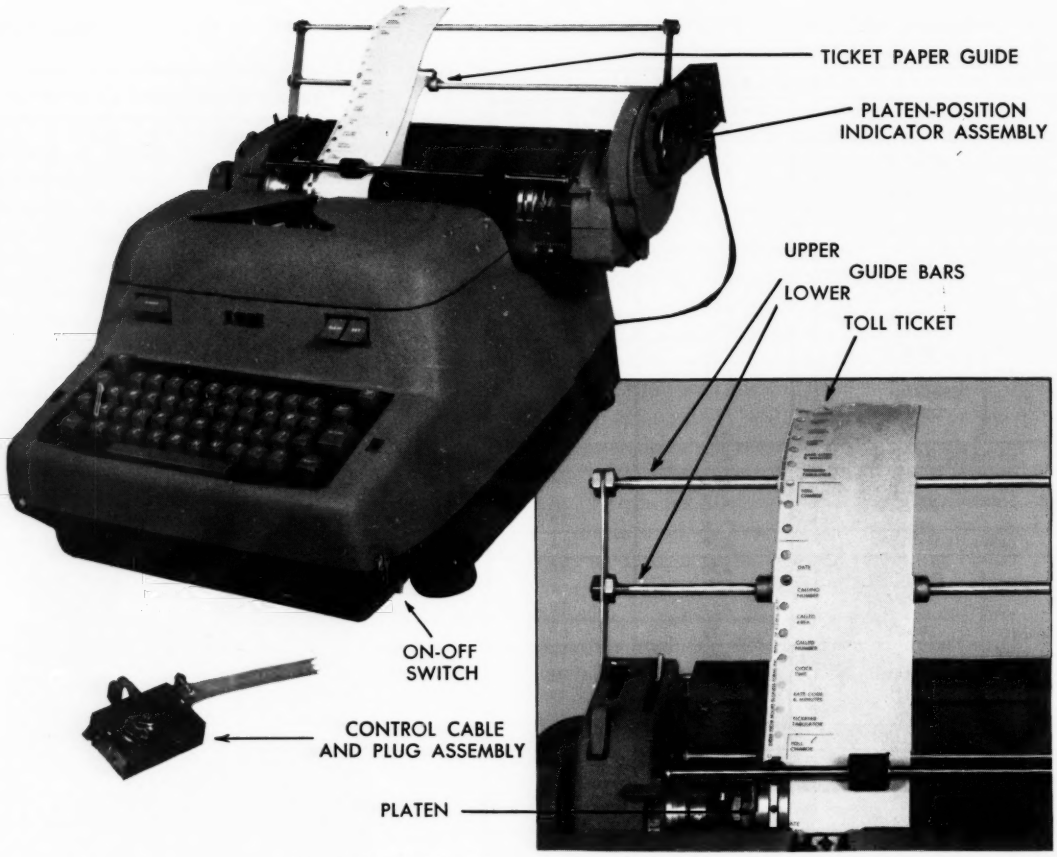


Figure 8. Ticket Printer with View of Toll Ticket in Position

Ticket Printer

This is a standard electric typewriter, purchased from IBM Corporation, and modified by addition of a platen position indicator assembly. It is designed for remote control operation; all control leads are brought out from the machine by means of a flexible cable terminating in a locking type connector. Figure 8 shows an overall view of this unit, and a close-up view of the printer with the tickets in position for printing. The latter view shows the holes along the left-hand edge of the tickets; these holes are engaged by the pins which project from the end of the platen, so that as the platen turns the tickets are pulled through the printer. The positive engagement between the pins and the holes prevents the paper from slipping and insures that the printing will always be in the correct position opposite the proper line of the form.

Should the platen be incorrectly positioned the printing operation will cease and an alarm will sound until the starting position of the platen has been corrected. This feature guards against tickets being printed "off-line" and is controlled by a set of gears which drives a cam on the end of the platen, actuating a snap action switch assembly. This apparatus is clearly shown in Figure 9.

Triple-line spacing is used between lines of the ticket form; however, the form line indicator is designed to detect any off-line condition, even a single-spaced line. Thus, any slippage or overthrow will be immediately detected so that corrective action may be started to remedy the fault. The circuit operation of the form line indicators is under control of the "platen-position" (PR) relay, which normally operates after the first line of the ticket is printed, and releases after the last line has been printed, preparing the circuit for the start of a new cycle.

Supervisory Unit

This consists of four lamps—DC Supply, Reader-Alarm, Printer-Alarm, Platen-Position—for visual indications, a buzzer for an audible alarm signal, and a peg-count meter (see Figure 10).

The DC supply lamp glows when battery and ground are connected to the ticket printer.

The platen-position lamp is used to aid the attendant in positioning the ticket paper in the printer. When it is properly aligned the platen cam springs will open the circuit to the platen position relay, PR. PR restores and closes ground to the platen position lamp, which glows.*

The printer-alarm lamp glows if the ticket printer and the Printroller are out of step. If the printer is not in the proper position, relay PR will operate and prepare the circuit to PE. The first toll ticket will be printed but when the rotary switch wipers advance to bank contact "N" the circuit to PE is closed. PA operates and closes ground to SS1 and PE. SS1 operates. PE operates and connects the printer from levels A and B to level C. PA operates, then restores. The wipers of the rotay switch advance. On bank No. 1, ground is closed to the carriage return magnet, and carriage return operates and restores. On bank contact No. 4, ground is closed to PD. PD operates, locks, opens PA to prevent its re-operation, and closes ground to the supervisory unit to light the printer-alarm lamp, which indicates an out-of-step condition. The audible alarm sounds.

The reader-alarm lamp indicates a tight tape or an out-of-tape condition in the reader. If either condition occurs, the short-circuit is removed from PJ. PJ operates in series with 1500-ohm resistor, R2. PJ opens PA, preventing it from re-operating, and closes multiple grounds to the supervisory unit to light the reader alarm lamp and operate the audible buzzer.

Operation of the toggle switch on the Supervisory cabinet closes the peg-count meter to "Release" relay PF. When this relay operates at the completion of a ticket, ground is closed from PF to operate the peg-count meter.

Refer to Schematic Circuit, Figure 11, Page 88.

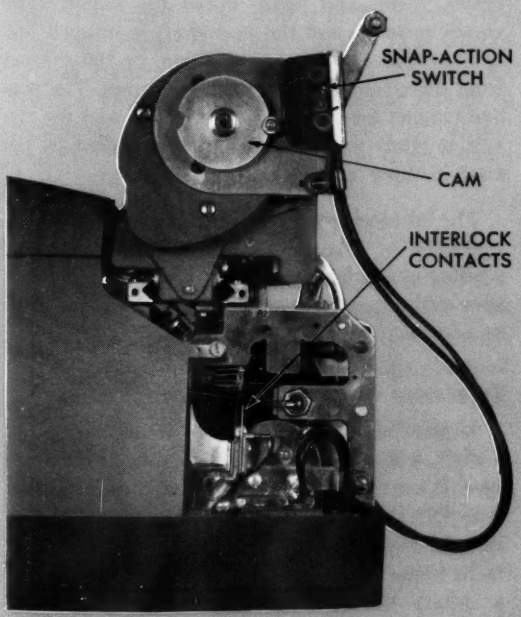


Figure 9. Snap Action Switch Assembly

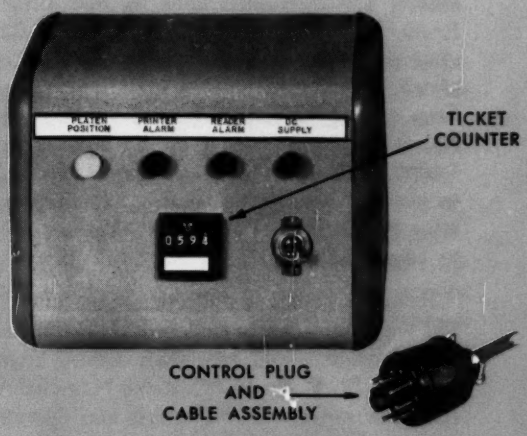


Figure 10. Supervisory Unit

Circuit Operation (Refer to Figure 11)

Relay PA of the Printroller functions as a "prime mover". Its No. 1 winding is wired to a ground-connected 4 MF capacitor, and No. 2 winding is wired to direct battery. These windings are connected in opposition when the relay's break springs are closed, and are connected in series aiding when the relay's break springs are open. This causes it to operate and release (pulse) automatically at a certain predetermined rate of speed.

Ground closed through the break contacts causes a current flow in both windings. As the windings are connected in opposition, the flux buildup is retarded until the current in the No. 1 winding has diminished sufficiently to be overpowered by that in the No. 2 winding; the relay then operates. However, as soon as the break springs open, the capacitor begins to discharge through the windings in the *series-aiding* direction so that the relay will operate fully. After the discharge current has diminished sufficiently, the relay begins its release. When the break contacts close, the relay will not operate immediately because of the time delay encountered during the charging of the capacitor. Thus, complete release is obtained.

In the following paragraphs where reference is made to operation or release of relay PA, automatic operation is being discussed.

Start

When the Printroller circuit is seized by operation of Reader switch S2, relays PS, PK, PA and the Reader clutch start operating. The circuit to SS1 is opened momentarily to prevent it from operating self-interrupted after its first step. The Reader cam shaft rotates. Cam springs RCC2 operate relay PB, opening the circuit to the Reader clutch, stopping the cam shaft rotation 180 degrees from starting, or reference, point of zero degrees. Relays W, X, Y and Z operate (assuming the "start" mark on the tape is being read) causing PC to operate. When PA operates, SS1 magnet and relay PH operate; however, SS1 does not advance its wipers at this time.

Relays PB, PA, PH and SS1 magnet restore, and SS1 wipers advance to bank contact No. 1. Reader clutch operates, and cam shaft rotates, restoring relays W, X, Y, Z and PC. Relay PC remains operated in series with PG which also operates to prepare the codel message circuit.

Translation and Printing of Digits

Relays PS, PC, PG, PK and the clutch are now operated. As the cam shaft rotates, the tape is moved to the next position for reading. Relay PB operates, locks, and opens the Reader clutch, which restores and stops the cam shaft 360 degrees from the previous position, or 180 degrees from the reference point of zero degrees.

If the first digit to be read from the tape is "0", this digit is marked by the "Z" hole punched in the tape. When the pin corresponding to this "Z" hole protrudes through the tape, the associated "Z" code contacts close a circuit which operates the "Z" relay in the Printroller. Relays PA, PH and SS1 magnet operate; relay PB releases. The circuit is closed to the "0" magnet in the Printer and this character is printed.

The circuit prepares to read the next digit. Relay PA restores, removing ground from PH and rotary magnet SS1. Rotary magnet SS1 restores and steps its wipers to bank contact No. 2. Relay PH restores, removes ground from the "0" print magnet and closes the clutch circuit. The cam shaft rotates and ground is removed from the "Z" codel relay. As the cam shaft rotates, the sensing pin is withdrawn from the hole in the message tape, the tape is advanced to the next position; cam springs operate, closing ground to PB; PB operates, locks, and again opens the clutch. The clutch restores, and the cam shaft is stopped 360 degrees from the previous position, or 180 degrees from the reference point of zero degrees. The pin-and-contact mechanism is re-operated and the circuit is ready to translate the second digit in the same manner as previously described.

The interlock contacts in the Printer control the operation of relays PA and PK, preventing the sending of a printing pulse to the Printer until the previously operated type bars have been restored to normal.

Sequencing

Sequencing, or the proper positioning of either a digit, a dot, a stroke, a space, or a carriage return, is controlled by the two rotary switches, SS1 and SS2. Two switches are used in multiple to speed this operation. While one switch is returning to its home position (following the completion of a ticket) the other switch is printing the next ticket.

Assume that a ticket (Figure 2) is to be printed, the data on the top line (Date) consists of two digits, a stroke, and two more digits. The first two positions are to be digits read from the tape; therefore, bank contacts No. 1 and No. 2 on SS1 and SS2 are multipled and strapped to the Tape Reader control contact on operating winding of relay PH. The first two digits are printed as previously described. As relay PA restores after the second digit, ground is removed from rotary magnet SS1 and relay PH. Wipers of SS1 advance to bank contact No. 3. Relay PH closes the circuit to the clutch of the Reader, which operates, allowing the cam shaft to rotate. The cam spring contacts open and allow the operated codel relays to release. The tape is advanced to the next position; cam spring contacts reclose and PB operates, opening the Reader clutch circuit. Again the cam shaft is stopped 360 degrees from the previous position, or 180 degrees from the reference point of zero degrees. Since a stroke (/) is to be placed between the second and third digits on the top line (Date), bank contact No. 3 is wired to the stroke magnet of the Printer. PA operates, closing ground to magnet SS1 and a stroke magnet of the Printer. The Printer prints a stroke (/) in the third position of the (Date) line, opening the interlock contacts which allow PK to restore. PA restores, removing ground from SS1 and the stroke magnet. SS1 advances its wipers to bank contact No. 4. Since a digit is required to be printed in the fourth position, this contact is strapped to the Tape Reader control contact. PK operates when the interlock contacts close after the stroke type-bar returns to its normal position. PA operates, and energizes SS1 and PH. PH operates, opens PB and closes ground to the third digit printer magnet.

Release

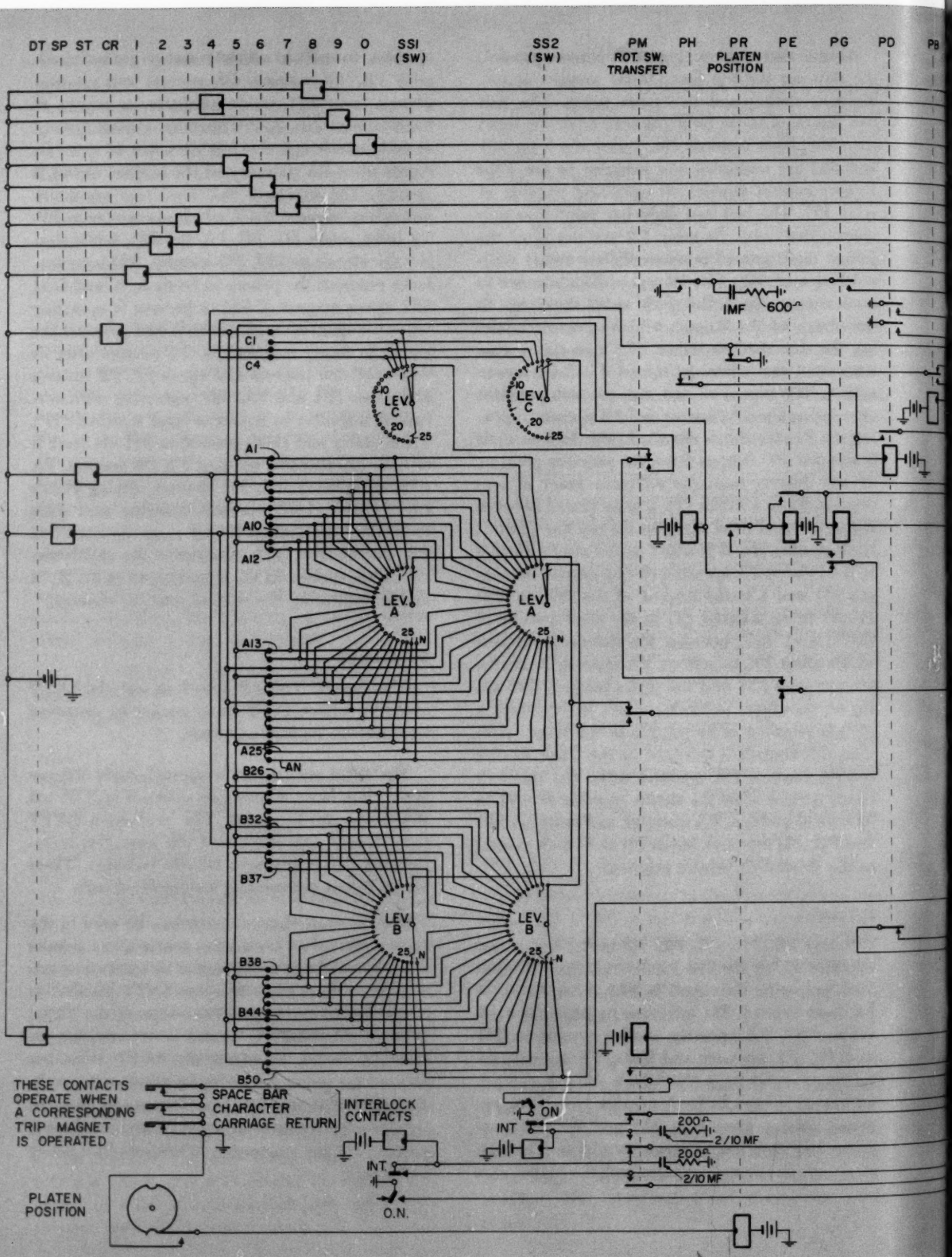
Relays PS, PK, PC, PB, PG and PR are now operated (after the first carriage return, PR operated, preparing the circuit to PE). After the ticket has been printed, SS1 advances its wipers to bank contact"N". PA operates, closing ground to SS1 and PE. PE operates and locks. PA restores, removing ground from SS1 which restores and advances its wipers to bank contact No. 1 PA operates, closing ground to SS1 and CR. SS1 operates but does not advance its wipers. The carriage return magnet operates and the platen cam operates its switch which removes ground from relay PR. PR restores. PA restores and removes ground from SS1 which advances its wipers to bank contact No. 2. PA operates, closing ground to SS1, which operates but does not advance its wipers until PA restores and the magnet circuit is opened. The wipers of "C" level now encounter ground on terminal No. 3, which operates relay PF. PF locks, opens PG, PC, PA and SS1, while closing the circuit to PM. PG restores. PM operates, locks, connects the printer to levels A, B, and C of SS2, opens magnet of SS2 to prevent it operating self-interrupted after its first step, and prepares the circuit to rotary magnet SS1. PC restores after its slow-to-release interval and opens PF. PF restores and closes SS1 and PA. SS1, operating self-interrupted, advances its wipers to bank terminal "N". PA operates and closes ground to PH via level B of SS2. PH operates, opening PB. PB restores. PA restores, opening PH. PH restores, closing clutch LRC. Clutch LRC operates, allowing cam shaft to rotate. Cam springs RCC2 close the circuit to PB. PB operates, locks and opens the clutch circuit. Cam springs RCC3 close ground to W, X, Y and Z, indicating the start of another message.

Summary:

The Type 57 Ticket Printer is an essential SATT accessory where SATT tapes cannot be processed by automatic business machines.

The ticket output rate is approximately 400 per hour; thus, in an 8-hour day, upwards of 3000 toll tickets can be produced. The perforated SATT tape records only completed toll messages; therefore, all tickets represent billable messages. There are no tickets representing uncompleted calls.

Two or more ticket printers can be used in the same exchange or accounting center if the volume of customer dialed traffic cannot be handled on one machine. Where more than one SATT installation is used by the same operating company, the Ticket Printers will usually be located in one common accounting center, to which the SATT tapes are shipped for processing daily, or at other intervals. As indicated above, these machines can be operated from regular commercial power; therefore, there is no need for any connection to central-office power facilities.


DT SP ST CR 1 2 3 4 5 6 7 8 9 0
SSI (SW)
SS2 (SW)
PM ROT. SW. TRANSFER
PH
PR PLATEN POSITION
PE
PG
PD
PB
IMF
600Ω
C1
C4
LEV. C
A1
A10
A12
A13
A25
AN
LEV. A
B26
B32
B37
B38
B44
B50
LEV. B
THESE CONTACTS OPERATE WHEN A CORRESPONDING TRIP MAGNET IS OPERATED
SPACE BAR
CHARACTER
CARRIAGE RETURN
INTERLOCK CONTACTS
INT.
O.N.
PLATEN POSITION
200Ω
2/10 MF

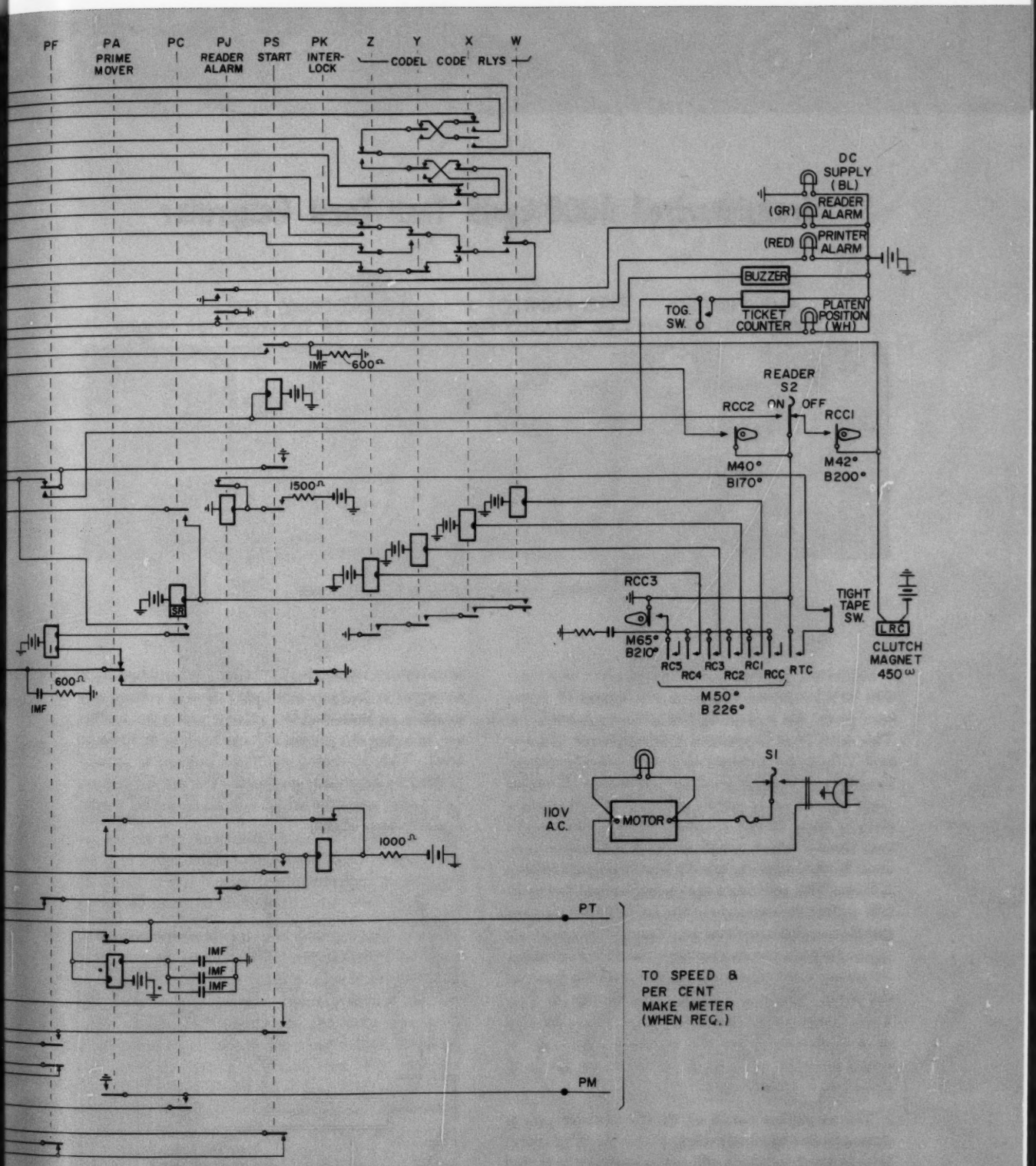


Figure 11. Schematic of Circuit Operation

Transistorized 1000-Cycle Test Tone Generator

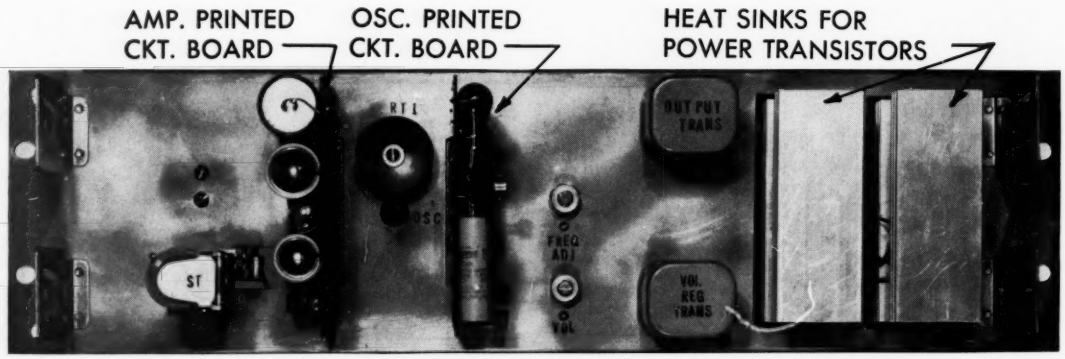


Figure 1. 1000-Cycle Test Tone Generator with Cover Removed

Solid-state physics has made another contribution to telecommnications—a new source of reference power for measuring loss in transmission lines. This new Tone Generator, a development of General Telephone Laboratories, will provide exceptionally stable output voltage regardless of variations in load or in supply voltage. It will operate directly from 48-volt exchange battery—an important feature which telephone men will appreciate, since it eliminates the need for wiring-in a 110-volt AC line. The unit has a maximum output power of 200 milliwatts—to supply up to 100 test circuits. Oscillator and amplifier sections are mounted on printed-circuit boards; locking-type adjustments for frequency and volume are mounted on the front of the panel. The new Transistorized 1000-cycle Test Tone Generator as shown in Figure 1 may be used as a replacement for the magneto-type unit; it comes complete with an attractive cover, and will mount on a 19-inch rack.

The operating circuit of the Tone Generator is shown in the block diagram, Figure 2. The signal is generated by the oscillator, amplified, and fed into the power transformer. The voltage-regulating transformer, connected to the output transformer, is arranged so that any attempted drop in voltage will result in an increased DC voltage across the oscillator, bringing the output voltage back to its original level. This increased oscillator voltage is accomplished by constantly comparing the output voltage to a 5-volt potential which is maintained by a voltage-reference diode.

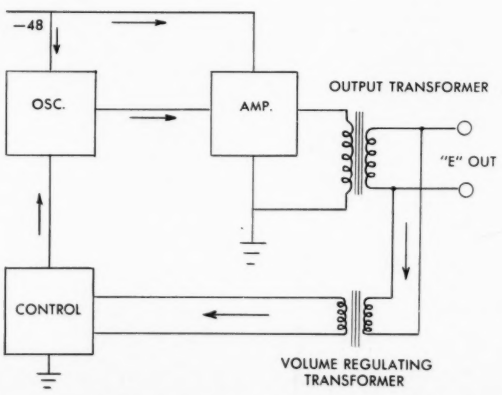


Figure 2. 1000-Cycle Test Tone Generator Operating Circuit

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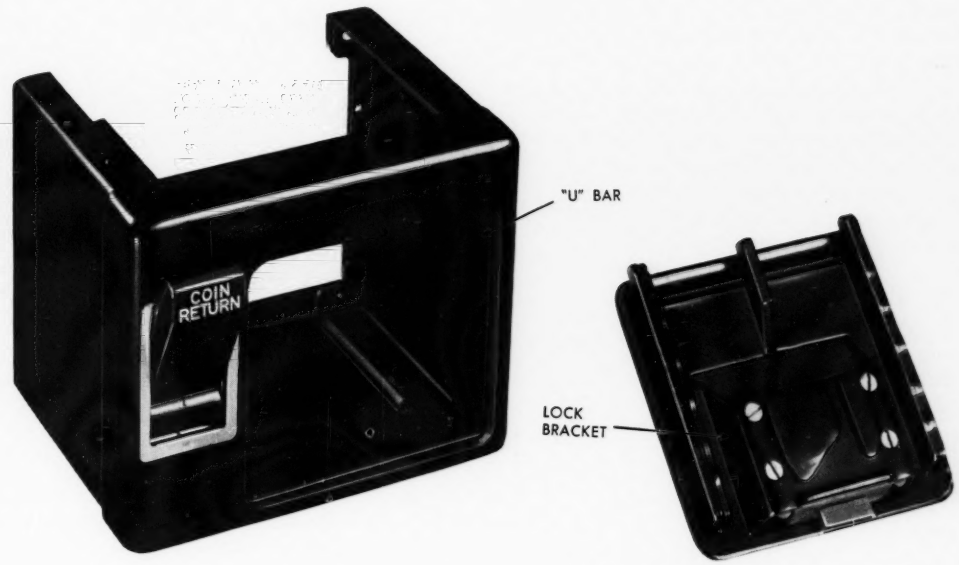
Burglar Resistant Paystation Coin Box



Coin Box with door removed to show design and construction.

Paystation telephones have been collecting more money than ever before; this has made them more susceptible to theft. Telephone men will be glad to know that the Automatic Electric paystation coin box and its associated parts have been re-designed. It is now much harder for anyone but authorized personnel to get at the coins in the box.

The housing and coin-box door are now made of heavier gauge steel and case-hardened. The door was made smaller and fitted so closely in the housing that it is impossible to insert a prying tool between them. The area over the door has been re-designed to eliminate the slope which formerly facilitated the use of a prying tool. The top and sides of the door frame have also been reinforced with a "U"-bar, arc-welded in place; this bar extends over the door opening, to serve as a door-stop.

The lock bracket has been reinforced, and is electrically welded to the door, making a single unit of great rigidity. Two other points of weakness were corrected: the lock-mounting holes were lowered to incorporate greater resistance to prying, and a fillet was added along the top and sides of the door.

To minimize the possibility of drilling or driving out the lock, it is completely covered by the hardened steel door—with the exception of the arc required for turning the key. Any attempt to drill the lock will almost certainly result in breaking the drill.

Before it was placed in production the new design was tested on a Baldwin Universal Testing Machine, using a ram on the inside corner of the coin-box door. It was found that a force of 5700 lbs. was required to separate the door from the surrounding frame. It would be impossible for any person to apply such leverage to the door of a paystation in service, since the prying instrument would have to have a razor-sharp edge, and this edge would break long before such a force could be exerted.

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About the Authors

RICHARD C. STILES, Senior Project Engineer, Research Department, General Telephone Laboratories, is presently responsible for research and development of electronic communications switching systems. He received his B.S. in E.E. from the University of Illinois. After four years as a radar officer in the U. S. Army Signal Corps, he participated in the early-warning ground radar activities, and later the U.S.A.F. Guided Missiles Program. In November, 1945, Mr. Stiles joined Automatic Electric and soon after was assigned to development work. He became a project engineer in 1950 and assumed responsibility for the current development of the Signal Corps Teletypewriter Switching Centers. Mr. Stiles is a member of the AIEE, and a recent recipient of the Talbot G. Martin Award.

THOMAS A. LONGO joined General Telephone Laboratories in 1958 as a Senior Project Engineer in the Research Department. Mr. Longo, a graduate of Purdue University, holds degrees of B.S., B.N.S., M.S., and Ph.D. After graduating from Purdue he remained on its staff as Assistant Professor of Physics, directing research on radiation effect in semiconductors, and silicon surface studies. He served for 4 years with the U.S.N.R., as a Lieutenant (senior grade). Mr. Longo is a member of Sigma Xi, Sigma Pi Sigma, and the American Physical Society.

ROBERT G. O'NEILL came to Automatic Electric in 1939, and was assigned to the Telephone Assembly Department. During the war he was chief inspector of Navy and Signal Corps field telephones. In 1946 he was transferred to the Quality Control Department assisting in the design and building of specialized test and control apparatus. In 1946 Mr. O'Neill became a member of the Testing Section of the Product Design Department of Laboratories. He is actively engaged in testing and analysis of products and materials for use in automatic telephony.